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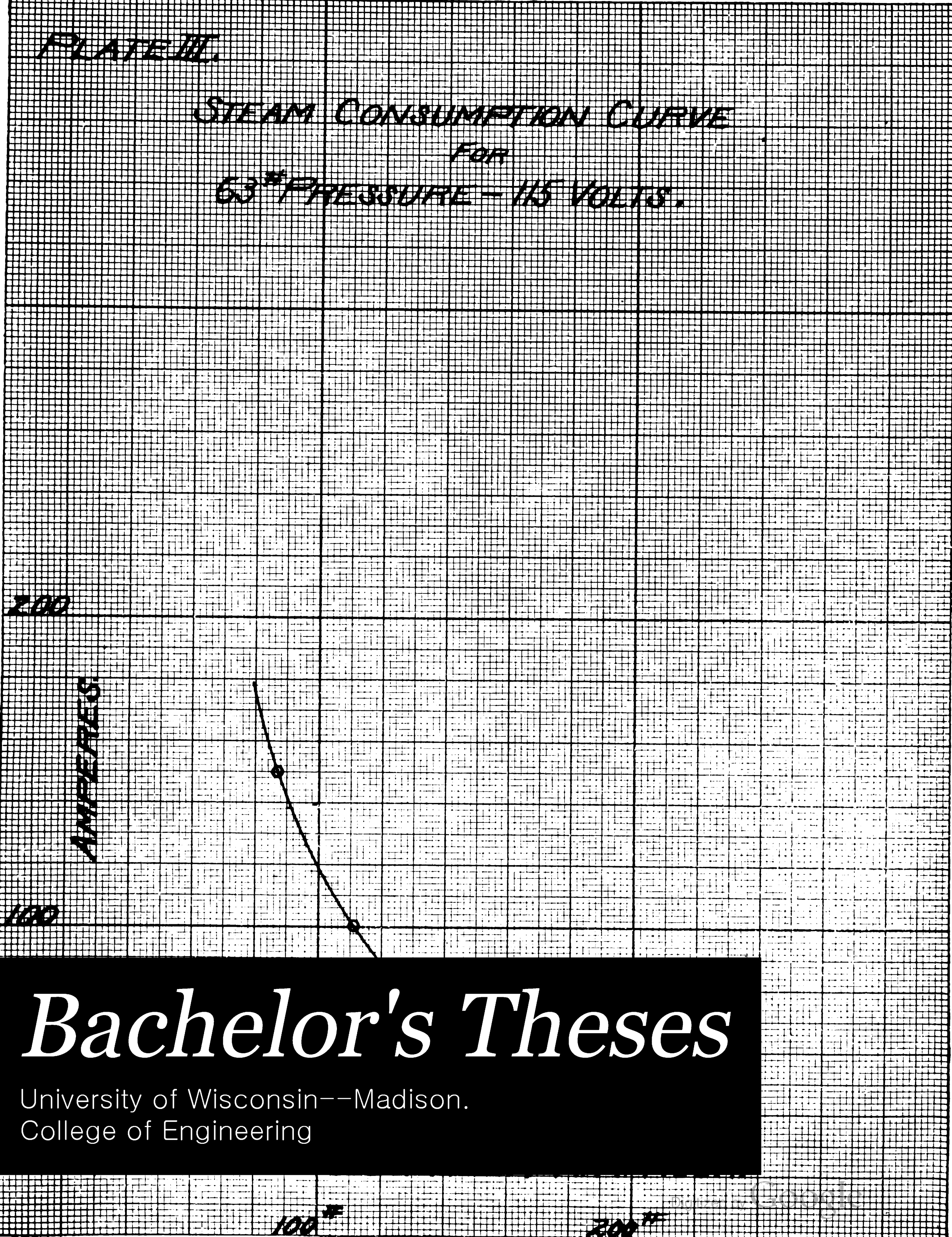

PLATE III.

STEAM CONSUMPTION CURVE
FOR
63# PRESSURE – 115 VOLTS.

Bachelor's Theses

University of Wisconsin--Madison.
College of Engineering

27p-4

A TEST OF SEVERAL METHODS OF RAILWAY CAR LIGHTING BY ELECTRICITY

BY

ALFRED ULYSSES HOEFER

AND

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A Thesis Submitted for the Degree of

BACHELOR OF SCIENCE

In the Mechanical Engineering Course

UNIVERSITY OF WISCONSIN

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CONTENTS

Page

INTRODUCTION - - - - - - - - 1

TEST OF CURTIS TURBO GENERATOR SET - - - - 2

TEST OF BATTERY EQUIPMENT - - - - - 25

TEST OF FARNSWORTH CONSOLIDATED AXLE EQUIPMENT - 39

INTRODUCTION

The lighting of railroad cars by electricity has during the last few years been given considerable thought and study. With the development of suitable apparatus for small lighting stations, came the application of electricity to railroad car lighting. The various systems employed for this purpose have been gradually improved, until today there are several which operate very satisfactorily, and are rapidly displacing other methods of train lighting because of the many advantages secured in the use of electric lights.

Hitherto, no very extended tests had been made on the different systems and it was for the purpose of investigating several equipments that this work was carried out. Tests were made on the following equipments of the Chicago, Burlington and Quincy Railroad; - Curtis Turbo Generator Set, Storage Battery Set, and Farnsworth Consolidated Axle Drive Set; reports of which follow.

TEST OF CURTIS TURBO GENERATOR SET

The test of this equipment was made on trains numbers 1 and 6, running between Chicago and Denver. The equipment consisted of a 25 K. W. Curtis Turbo-generator set mounted in the front end of the baggage car, there being an auxiliary of two sets of batteries in connection - one located under the baggage car and the other beneath a Pullman car at the rear of the train. The turbine receives its steam from the locomotive through a pipe line beneath the cars and flexible hose connectors between the cars, there being a reducing valve at the locomotive which reduces the steam pressure from that at the boiler to eighty pounds at the turbine.

THE TURBO GENERATOR SET is one manufactured by the GENERAL ELECTRIC CO. and is of the horizontal shaft type of 25 K. W. capacity, Type C - 2 - 25 - 3600, Form T, amperes, 200. The turbine is equipped with a governor which automatically regulates the speed by opening or closing poppet valves controlling the steam supply. The steam after leaving the turbine exhausts through a steam funnel into the air

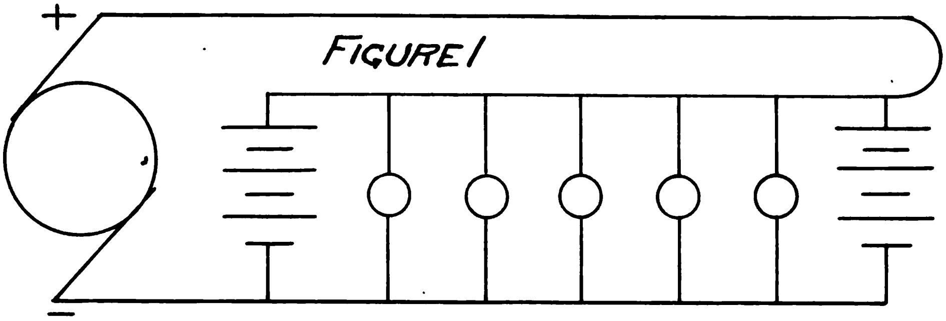
above the car, the funnel serving to drain back the water in the steam, thus preventing undue formation of ice on the cars in the winter time. Oil pressure is maintained at 6 pounds on the bearings by means of a chain pump.

THE SWITCHBOARD is conveniently mounted in the dynamo compartment and contains an ammeter and voltmeter of the Westinghouse type, and two steam gauges, one of which shows the pressure of the steam delivered to the turbine and the other the pressure of the steam delivered to the train heating line. The board also contains an automatic circuit-breaker designed to protect against both overload and underload. The underload attachment is provided so that in case the steam pressure is shut off the generator becomes inoperative the circuit will be automatically opened as the generator speed decreases, thus preventing the generator being driven as a motor by the batteries.

THE BATTERIES consist of two sets; one located on the baggage car and the other on a rear Pullman car. They are of the type 13 E made by the Electric Storage Battery Co. and are of 240 ampere hour capacity, 54 cells being supplied to each battery. These batteries are floated directly on the line and since they require no throwing of switches to place them on the line when the turbine is cut off, but are always ready for service on the lights, the arrangement adds to the

simplicity of the system.

THE TRAIN LINE is of peculiar construction. The method of distribution is that known as the "return loop" or "Werderman" construction and consists essentially of three wires running throughout the length of the entire train, located in the roofs of the cars. The positive wire as per Figure 1 runs to the rear of the train and loops back along the same path to the forward car of the train, the lights and batteries being connected between this return loop and the third wire which is connected directly to the negative terminal of the machine. The object of this construction is to obtain a more uniform distribution of potential along the line.



In addition to this there is a peculiarity in the construction of the train line which is characteristic of this equipment in that the two feeding wires are crossed within each car and also between each of the cars. This is for the purpose of preserving proper polarity in each of the wires in the car. The necessity for this is best shown by a com-

parison of the three figures shown here.

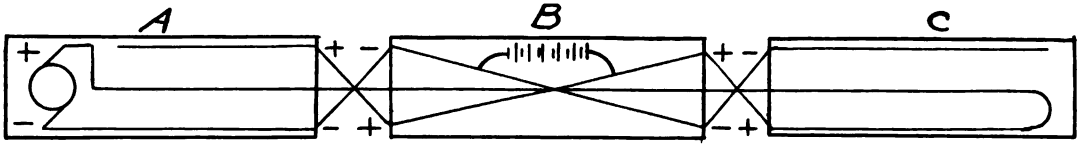


FIGURE 2.

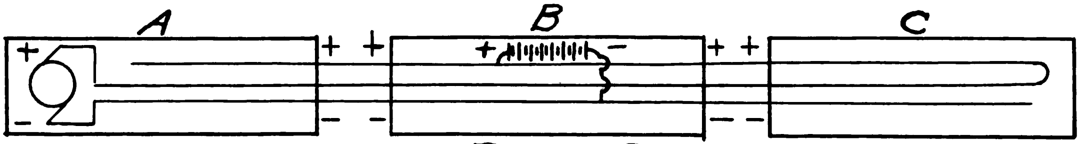


FIGURE 3.

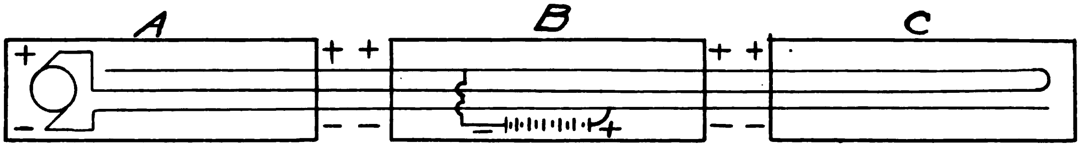
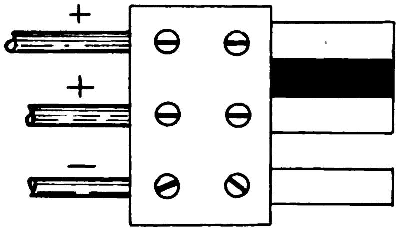


FIGURE 4.

In Figure 2 is shown the train line as in operation. It is obvious that no matter which end of the car B is forward, the same polarity of the generator will be presented to the batteries located on that car. It is also readily seen that if the train had been wired straight as per Figure 3, a battery being located on the middle car, and the middle car should be turned end for end as in Figure 4, the positive generator lead will be presented to the negative of the battery thus causing a direct short circuit of both generator

and battery through each other.

THE CONNECTORS between cars are of special type designed for this purpose, consisting of male and female parts, each of which has three insulated connections for accommodating the three train wires. The connector is shown roughly by the accompanying drawing of the male part. A hard rubber



block is placed between the two positive leads to insure that the male is placed in with the right side up. A thumb screw clamps the male solid after it is inserted into the female block and insures a good permanent contact. The leads between cars are of heavy flexible copper cable and are looped up and fastened to one side of the passage-way so as not to interfere with passage through the vestibule.

An individual SWITCHBOARD is included in the equipment of each car, containing switches and fuses for each of the light circuits. In the cars containing batteries there are also switches for the battery and train line.

An ELECTRICIAN is placed in charge of the equipment and is on the train throughout the whole trip, his duty being to maintain constant voltage, look to the operation of the tur-

bine, care for any emergencies that may arise in the operation of the equipment, and also to see that proper steam pressure is maintained on the train heating system.

METHOD OF TEST

The test of the equipment consisted in making two distinct tests - a road test to determine operating conditions, and a steam consumption test to determine the amount of steam consumed in the operation of the turbine.

The ROAD TEST was made on the turbo-generator on the train running between Chicago and Denver. During the test the turbine was equipped with a calibrated steam pressure gauge and separating calorimeter to determine steam pressure and quality. The gauge was placed in the pipe line about a foot from the turbine. The separating calorimeter tap was located in a T pipe connector at the point where the pipe line enters the generator compartment, as shown in Figure 5.

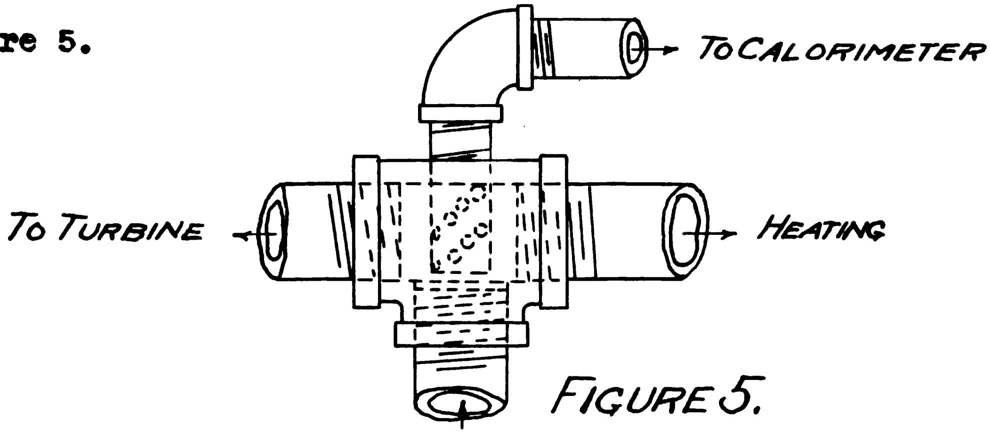


FIGURE 5.

At this point the steam has not as yet passed through the separator and hence no consideration was made of the separator water - this being all included in the moisture of the steam as indicated by the calorimeter readings.

In order to determine the electrical operation of the equipment a calibrated ammeter was placed in the generator circuit and a calibrated voltmeter was placed across the generator terminals.

The speed of the generator was determined by means of a stop watch and speed indicator.

Readings were taken at fifteen minute intervals when lights were turned on throughout the entire trip. When the lights were on the batteries, readings of battery voltage and current were taken of each set, and the total time of operation of lights on the batteries was noted. The pressure of oil on the bearings was noted occasionally and the general operation was watched closely throughout the test.

The STEAM CONSUMPTION TEST was made on the turbo generator in the laboratory of the University of Wisconsin. It was the intention to make the steam consumption test in the yards at Chicago but after equipping one of the turbine sets for the test in the yards, it was found that sufficient cooling water could not be obtained to condense the steam and accordingly it was decided to make the test in the laboratory.

of the University, where there was installed this year, a turbo-generator set identical with that tested on trains 1 and 6.

A surface steam condenser was connected to the exhaust pipe and served to condense the steam passing through the turbine. The condensed steam was weighed after passing through the turbine on standard Fairbank's platform scales, at exact five minute intervals.

The load was applied to the generator by means of a water-box and measurements of current and voltage were made by calibrated Weston instruments.

Steam pressure and quality were determined by means of a pressure gauge and a throttling calorimeter tapped into a vertical section of the pipe at the turbine.

The back pressure was read on a manometer tube tapped into the exhaust pipe.

Speed was determined by means of a stop watch and speed indicator.

Data was taken for 1/4, 1/2, 3/4, 1, 1-1/4 loads and for steam pressures of 60 pounds, 70 pounds, 80 pounds and 90 pounds. Readings were taken every thirty minutes throughout the test. The voltage was kept the same as is used on the train service, and the load and steam pressure were kept constant during each run.

DISCUSSION OF RESULTS

The most striking result of the ROAD TEST is the fact that the generator load is never above 17 K. W. and the average load is less than 11 K. W. This is significant since the machine is rated at 25 K. W. It would seem to indicate poor judgment in the selection of the equipment, but in justice to the operating department of the railroad it must be said that efficiency of operation is not the mere relation of output and input, but in service on the railroad a vast number of other considerations enter which reduce the efficiency and cost of operation to secondary importance. In the case of train lighting it is necessary that the railroad be prepared to handle very heavy traffic at certain rush seasons - in many cases the length of passenger trains being doubled. This requires a proportionally heavy lighting capacity, which, though lasting but a few days, must still be taken into consideration in the selection of such an equipment.

Another feature which warrants the adoption of such a large capacity set is that for low steam pressures - such as

60 pounds - which frequently occur, the turbine can deliver but half or three-quarter load. A 25 K. W. generator will carry the load at this pressure, but a 15 or 20 K. W. generator would not be able to carry the load under the same conditions and hence the generator at this point would become inoperative.

A fact which deserves attention is that the steam consumption over the entire trip does not vary from full load to the lighter loads as much as might be expected, as is shown by consideration of the steam comsumption curves on Plate I and II. The maximum variation of steam consumption is shown to be 1480 pounds per hour at 17 K. W. and 800 pounds per hour at 4.3 K. W.

The speed of the generator varies almost directly with the steam pressure when operating under heavy load, but upon light loads remains practically constant.

It is readily seen from a comparison of the curves of load and steam consumption per K. W. hour that the steam consumption varies inversely as the load - this tending to make the total steam consumed more nearly constant at the various loads.

The results of the STEAM CONSUMPTION test show remarkable results. In the first place it was found that the steam consumption curves for all the pressures employed were

identical - showing that for variations of steam pressure between 60 pounds and 90 pounds the steam comsumption is independent of the pressure. The only explanation that can be offered for this is that there is a throttling action of the governor that takes place which tends to maintain the pressure on the nozzles more or less constant irrespective of the pressure impressed on the turbine. The steam consumption curves are shown in Plates III to X.

The steam consumption is higher than is to be expected from a reciprocating engine of a similar capacity, but an explanation of that fact is not within the scope of this investigation and so will not be considered here.

By reference to the tables,[1] it may be noted with what care this test was made in that the steam consumption for various five minute intervals check on each other very closely.

Data of Trip on Train, Number 1
From Chicago to Denver, February 9, 1906
Turbo-generator in Baggage-car, Number 1350

Time P. M.	Steam Pressure	Quality of Steam	Speed	Volts	Amperes	Output in K. W.	Pounds of Wet Steam per K. W. Hour
4:20	58.5			112.8	83.0	9.35	124
4:50	84.0		3600	112.8	139.5	15.75	90
5:10	78.0			114.0	149.5	17.05	85
5:30	72.0	98.5	3530	112.8	143.4	16.20	90
6:00	76.0	98.3	3545	112.8	133.4	15.05	94
6:30	69.5	98.6	3580	112.8	135.0	15.21	93
7:00	76.0	98.3	3560	112.0	134.4	15.07	93
7:30	88.0	98.3	3580	112.8	135.0	15.21	93
8:00	86.0	98.3	3560	114.0	142.5	16.25	88
8:30	84.0		3600	112.8	134.4	15.15	92
6:45	86.0	98.4	3600	114.0	134.4	15.35	92
9:00	87.0		3600	112.8	134.4	15.15	92
9:15	86.0		3565	112.8	132.4	14.95	93
9:30	84.0	98.5	3560	112.8	132.4	14.95	93
9:45	83.0	98.4	3530	112.8	135.0	15.21	92
10:00	84.0	98.2	3530	112.8	132.4	14.95	93
10:15	83.0		3535	112.8	130.0	14.65	95
10:26	83.0		3535	112.8	130.0	14.65	95
			Battery				
10:26				110.5	89.0	9.78	
10:30				99.5	100.0	9.93	
10:32				103.0	67.0	6.90	
10:35				105.5	48.0	5.02	
10:42				104.7	48.0	4.97	
10:45				101.7	68.5	6.96	
10:45	44.5			113.0	84.0	9.50	123
11:00	81.0		3530	113.5	81.0	9.20	126
11:15	77.0			114.2	80.5	9.20	126
11:30	88.0	98.5	3600	114.0	61.0	6.96	147
11:45	83.0		3640	114.0	60.7	6.95	147
12:00	88.0	97.1	3630	114.0	61.0	6.96	147

12:15	86.0	98.3	3600	114.0	61.0	6.96	147
12:30	88.0	98.5	3600	111.3	58.0	6.56	152
12:45	85.0			114.0	45.0	5.13	172
1:00	92.0	98.0	3615	114.0	49.0	5.59	164
1:15	88.0	98.3	3600	114.0	58.0	6.61	150
1:30	90.0	97.7		114.0	43.0	4.91	183
1:45	84.0	97.8	3600	114.0	41.0	4.68	190
2:00	88.0			112.8	41.0	4.62	190
2:15	93.0	97.5	3645	112.8	37.0	4.17	205
2:30	90.5			112.8	36.0	4.06	205
2:45	84.5	97.6		112.8	41.0	4.62	190
3:00	80.0			112.8	34.0	3.83	210
3:15	83.0		3580	114.0	37.0	4.21	205
3:21	83.0		3580	114.0	37.0	4.21	205

Battery

3:21	114.0	25.0	2.85
3:24	110.2	29.0	3.20
3:28	108.5	29.5	3.20
3:30	108.5	29.0	3.15
3:35	108.0	29.0	3.14

3:35	68.0			112.8	61.0	6.87	146
3:45	60.0			112.8	62.0	6.99	146
4:00	63.0	97.5	3550	117.0	46.0	5.37	175
4:15	43.0	97.6	3530	117.0	44.5	5.21	179
4:30	45.0			118.0	47.5	5.61	118
4:45	48.5	97.6	3550	117.0	40.0	4.67	182
5:00	50.5			117.0	33.5	3.92	198
5:15	50.5		3600	117.0	34.2	4.00	196
5:30	49.5			118.0	32.0	3.78	200
6:00	40.0			110.0	47.0	5.17	168
6:30	42.0	97.8	3600	119.0	40.0	4.76	182
6:45	38.0			119.0	39.0	4.64	186
7:00	45.0	97.8	3600	119.0	39.0	4.64	186
7:15	45.0			119.0	39.0	4.64	186

Battery

7:15	115.5	24.5	2.82
7:20	112.0	17.0	1.89
7:25	112.5	17.4	1.89
7:30	112.8	17.2	1.89

7:30	60.0		3600	117.0	30.0	3.51	205
7:45	60.0			117.0	30.0	3.51	205
7:55	65.0	98.8	3600	118.0	24.0	2.83	215
8:00	65.0			118.0	24.0	2.83	215

February 10

P. M.

6:00	55.0	96.2	3600	116.0	20.0	2.32	220
6:15	56.0			119.0	27.0	3.21	216
6:30	54.0	97.4	3600	115,0	66.0	7.58	140
6:45	50.0			112.8	113.5	12.80	102
7:00	52.0	97.2	3600	112.0	117.5	13.15	100
7:15	53.0			112.0	117.5	13.15	100
7:30	51.0		3450	112.0	126.5	14.15	96
7:45	53.0			112.8	123.0	13.86	98
8:00	54.0		3440	112.8	122.0	13.75	99
8:15	54.0			115.0	129.0	14.85	95
8:30	54.0			115.0	129.0	14.85	95

Battery

8:30				100.5	99.0	10.0
8:35				100.0	95.0	9.5
8:40				100.0	73.0	7.3

Time generator in operation - 17 hours, 22 minutes.

Time batteries in operation - - - 58 minutes.

Total steam used - - - - 19,356 pounds.

Date of Trip on Train, Number 6
From Denver to Chicago, February 12, 1906
Turbo-generator in Baggage-car, Number 1349

Time P. M.	Steam Pressure	Quality of Steam	Speed	Volts	Amperes	Output in K. W.	Pounds of Wet Steam per K. W. Hour
6:24	72.0			118.0	49.0	5.78	167
6:30	70.0	97.8	3600	115.0	98.0	11.28	110
6:45	71.0	97.6	3600	115.0	126.5	14.55	94
7:00	68.0			116.0	129.5	15.02	92
7:15	68.0	97.6	3590	115.0	127.0	14.60	93
7:30	69.0			115.0	118.0	13.58	97
7:45	66.0	97.8	3500	115.0	125.0	14.38	92
8:00	63.0			113.0	116.5	13.18	97
8:15	66.0	97.6	3600	113.0	115.0	13.00	98
8:30	72.5			116.5	133.0	15.50	90
8:45	77.0	97.4	3600	117.5	135.0	15.85	90
9:00	73.0			116.5	128.0	14.92	92
9:15	76.0	97.8	3587	117.5	130.0	15.28	92
9:30	88.0			115.0	130.0	14.95	92
9:45	88.0	98.8	3580	116.0	123.0	14.28	96
10:00	82.0			115.0	115.0	13.22	100
10:15	85.0	97.6	3500	115.0	86.0	9.88	120
10:30	85.5			115.0	86.0	9.88	120
10:45	86.0	97.5	3600	115.0	77.0	8.85	127
11:00	78.0			115.0	81.0	9.31	124
11:15	82.0	97.2	3600	116.0	81.0	9.40	124
11:30	78.0			117.0	79.0	9.25	125
11:40	78.0			117.0	79.0	9.25	125
				Battery			
11:40				117.0	60.0	6.42	
11:45				102.5	47.5	4.87	
11:50				103.0	37.8	3.91	
11:50	68.0			115.0	71.0	8.16	136
11:55	68.0			115.0	71.0	8.16	136
12:00	75.0			116.0	81.0	9.40	126
12:15	56.5	98.2	3650	116.0	86.0	9.98	122
12:30	66.0			116.0	57.0	6.62	153
12:45	66.0		3700	116.0	54.0	6.27	157
1:00	66.0	97.0	3710	116.0	51.0	5.92	160

1:15	66.0	97.2	3700	115.0	54.0	6.21	157
1:30	66.0		3680	115.0	59.0	6.78	150
1:45	66.0		3630	116.0	56.0	6.50	154
2:00	66.0	98.8	3600	116.0	56.0	6.50	154
2:15	56.5		3660	116.0	41.0	4.76	180
2:30	41.0		3570	120.0	71.0	8.52	136
2:45	44.0	96.6	3650	120.0	63.0	7.56	146
3:00	37.0		3300	120.0	69.0	8.27	137
3:15	40.0	96.6	3360	120.5	71.0	8.55	136
3:30	41.0		3400	120.0	67.0	8.04	140
3:45	37.0	95.8	3360	120.0	54.0	6.48	156
4:00	34.5	96.2	3340	120.0	47.0	5.64	168
4:15	38.0		3320	120.0	56.5	6.78	153
4:30	36.0	96.2		120.0	49.5	5.94	164
4:45	36.0		3300	119.0	49.0	5.83	164
5:00	41.0			120.0	58.0	6.96	150
5:15	41.0			120.0	58.0	6.96	150

Battery

5:15				110.0	35.7	3.93	
5:20				110.0	27.7	3.06	
5:30				108.5	35.7	3.88	
5:35				106.5	39.5	4.22	
5:40				106.0	42.0	4.46	
5:45				105.5	41.2	4.35	

5:45	72.5		3625	114.0	48.5	5.53	164
6:00	72.5			114.0	48.5	5.53	164
6:15	72.0			114.0	47.0	5.36	168
7:00	94.5	96.0	3780	115.0	51.0	5.82	162
7:15	86.0			115.0	56.0	6.44	153

February 13

P. M.

5:00	82.0			115.0	51.0	5.87	162
5:15	82.5	96.4	3600	115.0	142.0	16.34	90
5:30	64.0		3543	116.0	146.0	16.95	88
5:45	73.0	96.7	3590	115.0	141.5	16.30	90
6:00	72.5		3685	115.0	139.5	16.05	91

6:15	57.0	96.4		115.0	140.0	16.10	91
6:30	58.5		3300	113.0	140.0	15.81	91
6:45	62.5	95.6	3310	115.5	147.0	16.98	88
7:00	63.5		3470	115.2	142.5	16.45	90
7:15	60.0	95.6	3670	115.0	139.0	16.00	91
7:30	56.5		3500	114.0	134.0	15.28	92
7:45	56.5	95.6		111.0	132.0	14.65	93
8:00	53.5		2975	110.0	126.0	13.87	96
8:15	51.5			109.0	123.0	13.40	98
8:30	51.5	95,5	2950	103.0	117.5	12.10	101
8:45	56.5			111.0	141.5	15.70	90
9:00	51.5			103.0	117.0	12.05	101
9:15	51.5			103.0	117.0	12.05	101

Time generator in operation - 17 hours, 26 minutes.

Time batteries in operation - - - 40 minutes.

Total steam used - - - - 19,811 pounds.

STEAM CONSUMPTION TEST

MARCH 9, 1906

STEAM PRESSURE, 63 POUNDS

Time A. M.	Weight of Steam	Quality of Steam	Speed	Back Pressure Inches Mercury	Out-put in K. W.	Pounds of Steam per K. W. Hour	
						Wet	Dry
		Load, 50 Amperes at 115 Volts					
9:35		98.3	3550	.100	5.75		
9:40	77.0	98.6	3540	.000	5.75		
9:45	77.0	98.9	3538	.005	5.75		
9:50	82.0	98.7	3562	.000	5.75		
9:55	77.0	98.8	3540	.000	5.75		
10:00	81,5	98.8	3550	.005	5.75		
10:05	77.0	98.8	3555	.000	5.75		
	471.5					164.0	162.0
		Load, 70 Amperes at 115 Volts					
8:05		98.7	3525	.100	8.05		
8:10	91.0	98.5	3540	.100	8.05		
8:15	91.0	98.6	3552	.100	8.05		
8:20	93.0	98.8	3540	.100	8.05		
8:25	91.0	98.6	3520	.100	8.05		
8:30	91.0	98.7	3547	.100	8.05		
8:35	93.0	98.8	3560	.100	8.05		
	550.0					136.8	135.0
		Load, 100 Amperes at 115 Volts					
8:35		98.8	3528	.100	11.5		
8:40	107.0	98.6	3515	.005	11.5		
8:45	106.0	98.7	3540	.008	11.5		
8:50	106.5	98.8	3535	.100	11.5		
8:55	108.0	98.7	3550	.000	11.5		
9:00	103.0	98.8	3558	.100	11.25		
9:05	106.0	98.8	3542	.100	11.45		
	636.5					111.0	109.4

Load, 150 Amperes at 115 Volts

9:05		98.8	3530	.100	17.25		
9:10	126.0	98.4	3528	.100	17.25		
9:15	126.0	98.2	3535	.100	17.25		
9:20	128.5	98.5	3540	.050	17.25		
9:25	127.0	98.3	3560	.050	17.25		
9:30	122.0	98.5	3555	.100	17.25		
9:35	122.0	98.3	3538	.100	17.25		
	751.5					87.3	86.0

STEAM PRESSURE, 74 POUNDS

P. M.

Load, 50 Amperes at 115 Volts

4:00		98.7	3555	.150	5.75		
4:05	80.0	99.1	3555	.100	5,75		
4:10	80.0	99.1	3535	.100	5.75		
4:15	81.0	99.0	3540	.100	5.75		
4:20	90.0	99.3	3570	.100	5.75		
4:25	80.0	99.3	3520	.100	5.75		
4:30	80.0	99.0	3555	.100	5.75		
	481.0					167.3	166.0

Load, 75 Amperes at 115 Volts

4:30		99.0	3555	.100	8.63		
4:35	91.0	98.8	3545	.100	8.63		
4:40	92.0	98.7	3550	.100	8.63		
4:45	91.0	98.9	3560	.100	8.63		
4:50	91.0	98.9	3550	.100	8.63		
4:55	91.0	98.9	3560	.100	8.63		
5:00	92.0	98.6	3530	.150	8.63		
	548.0					127.0	125.5

Load, 100 Amperes at 115 Volts

5:00		98,6	3530	.150	11.5		
5:05	102.0	98.7	3525	.150	11.5		
5:10	103.0	98.8	3565	.150	11.5		
5:15	102.0	98.9	3550	.150	11.5		
5:20	105.0	98.7	3550	.150	11.5		
5:25	102.0	98.9	3540	.150	11.5		
5:30	105.0	98.8	3545	.150	11.5		
	619.0					107.6	106.5

Load, 150 Amperes at 115 Volts

5:30		98.8	3545	.150	17.25		
5:35	123.0	98.7	3560	.100	17.25		
5:40	125.0	98.9	3560	.100	17.25		
5:45	123.0	98.9	3530	.100	17.25		
5:50	121.5	98.9	3525	.100	17.25		
	492.5					85.5	84.0

STEAM PRESSURE, 84 POUNDS

P. M.

Load, 50 Amperes at 115 Volts

1:30		98.8	3520	.200	5.75		
1:35	80.0	99.2	3590	.050	5.75		
1:40	78.0	99.3	3600	.050	5.75		
1:45	80.0	99.3	3600	.050	5.75		
1:50	81.0	99.4	3600	.050	5.75		
1:55	82.0	99.2	3590	.100	5.75		
2:00	83.5	99.2	3600	.100	5.75		
	484.5					168.5	167.0

Load, 75 Amperes at 115 Volts

2:00		99.2	3600	.100	8.63		
2:05	91.0	98.8	3575	.100	8.63		
2:10	92.0	98.8	3560	.050	8.63		
2:15	92.5	98.9	3570	.050	8.63		
2:20	91.0	98.9	3548	.100	8.63		
2:25	91.5	99.0	3660	.100	8.63		
2:30	92.0	98.7	3535	.100	8.63		
	550.0					127.5	126.2

Load, 100 Amperes at 115 Volts

2:30		98.7	3535	.100	11.5		
2:35	106.0	98.6	3500	.100	11.5		
2:40	105.0	98.6	3525	.100	11.5		
2:45	105.0	98.8	3527	.050	11.5		
2:50	102.5	99.1	3545	.050	11.5		
2:55	102.0	99.1	3542	.100	11.5		
3:00	104.0	99.1	3525	.100	11.5		
	624.5					108.5	107.3

Load, 150 Amperes at 115 Volts

3:00		99.1	3525	.100	17.25		
3:05	124.0	99.1	3560	.100	17.25		
3:10	124.0	99.1	3510	.100	17.25		
3:15	125.0	99.1	3515	.100	17.25		
3:20	124.0	99.1	3520	.100	17.25		
3:25	121.0	99.0	3525	.100	17.25		
3:30	124.0	98.9	3515	.100	17.25		
	742.0					86.0	85.0

STEAM PRESSURE, 94 POUNDS

A. M.

Load, 50 Amperes at 115 Volts

10:05		98.8	3600	.050	5.75		
10:10	83.0	98.8	3600	.050	5.75		
10:15	77.0	99.0	3585	.000	5.75		
10:20	82.0	98.7	3600	.000	5.75		
10:25	81.0	98.8	3580	.000	5.75		
10:30	80.0	98.5	3560	.000	5,75		
10:35	80.5	98.5	3580	.000	5.75		
	483.5					168.0	166.2

Load, 75 Amperes at 115 Volts

10:35		98.5	3600	.000	8.63		
10:40	95.0	96.8	3565	.000	8.63		
10:45	96.5	96.3	3545	.000	8.63		
10:50	98.0	98.0	3600	.000	8.63		
10:55	91.0	98.7	3540	.000	8.63		
11:00	92.0	98.8	3540	.000	8.63		
11:05	90.0	98.5	3560	.000	8.63		
	562.5					130.0	126.0

Load, 100 Amperes at 115 Volts

11:05		98.5	3560	.050	11.5		
11:10	105.0	96.5	3530	.000	11.5		
11:15	107.0	97.8	3560	.000	11.5		
11:20	103.0	98.5	3550	.050	11.5		
11.25	102.0	98.5	3550	.050	11.5		
11:30	102.0	98.2	3545	.000	11.5		
11:35	103.0	98.5	3540	.050	11.5		
	622.0					108.5	105.0

Load, 150 Amperes at 115 Volts

11:35		97.2	3540	.050	17.25		
11:40	126.0	98.0	3540	.050	17.25		
11:45	124.5	98.4	3535	.050	17.25		
11:50	124.0	98.5	3530	.050	17.25		
11:55	124.5	98.3	3525	.050	17.25		
12:00	124.0	98.1	3525	.050	17.25		
12:05	122.0	96.5	3525	.050	17.25		
	746.0					84.5	82.8

Load, 200 Amperes at 115 Volts

12:05		98.1	3625	.150	23.00		
12:10	148.0	96.5	3510	.150	23.00		
12:15	144.0	98.8	3500	.150	23.00		
12:20	147.5	98.2	3520	.150	23.00		
12:25	146.0	97.5	3535	.150	23.00		
12:30	152.5	97.7	3510	.150	23.00		
12:35	145.0	98.0	3500	.150	23.00		
	883.0					76.8	74.5

Load, 250 Amperes at 115 Volts

1:00		98.4	3300	.200	28.7		
1:05	175.5	98.5	3480	.200	28.7		
1:10	163.0	98.4	3490	.200	28.7		
1:15	163.0	98.4	3500	.200	28.7		
1.20	166.5	98.5	3500	.200	28.7		
1:25	166.5	98.8	3520	.200	28.7		
1:30	165.0	98.8	3520	.200	28.7		
	999.5					69.4	68.3

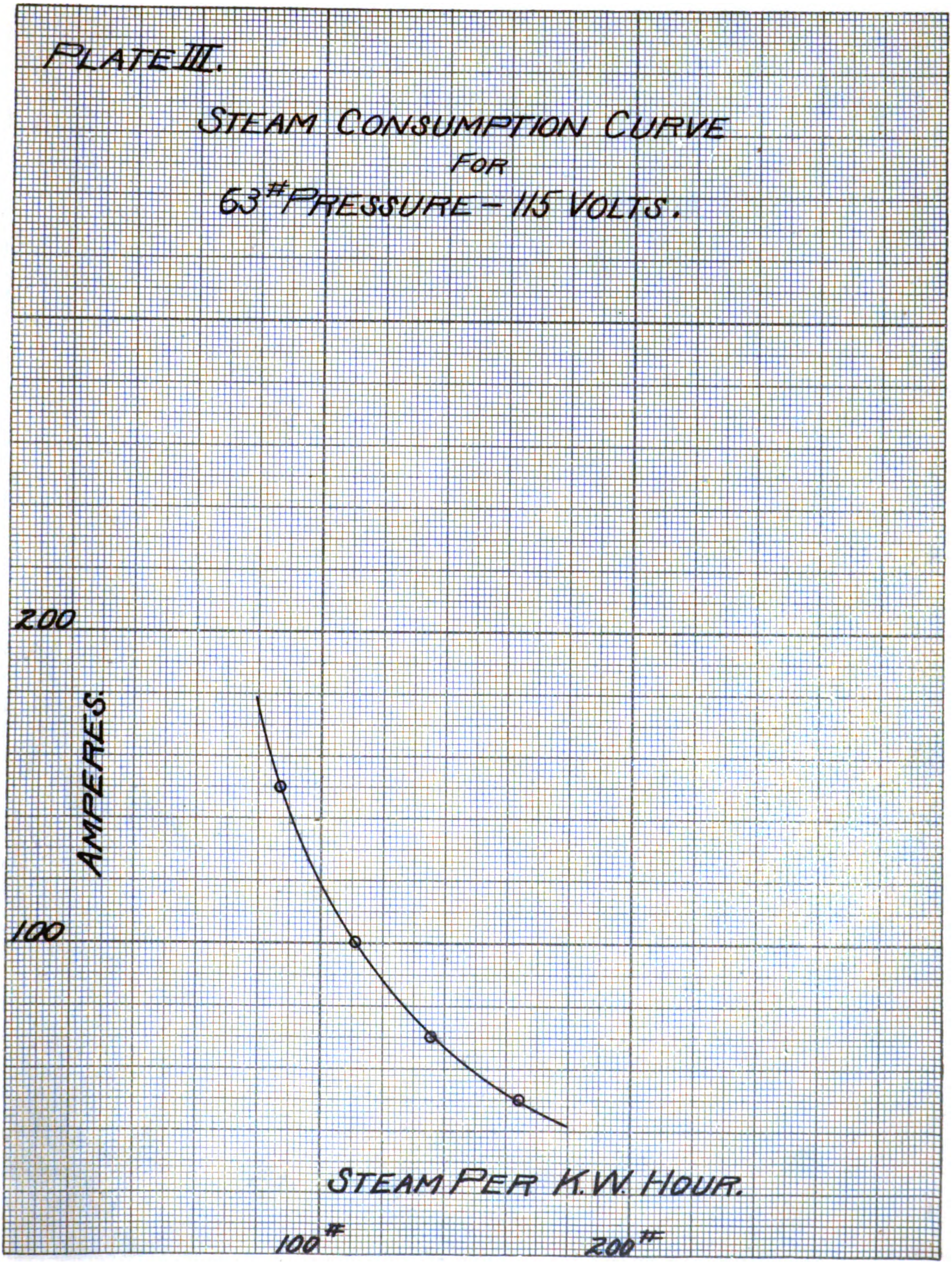


PLATE III.

STEAM CONSUMPTION CURVE
FOR
63# PRESSURE – 115 VOLTS.

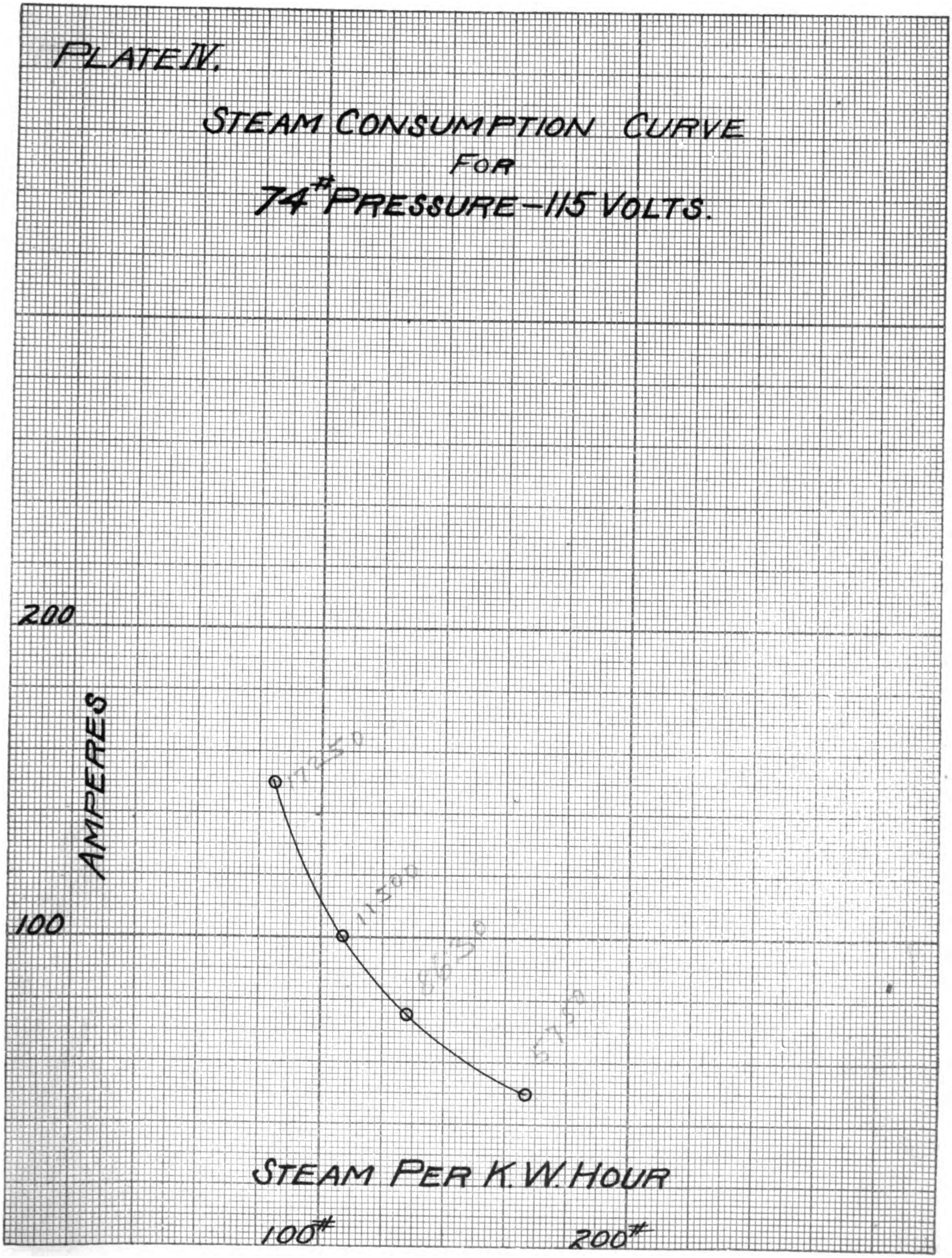


PLATE IV.

STEAM CONSUMPTION CURVE
FOR
74# PRESSURE–115 VOLTS.

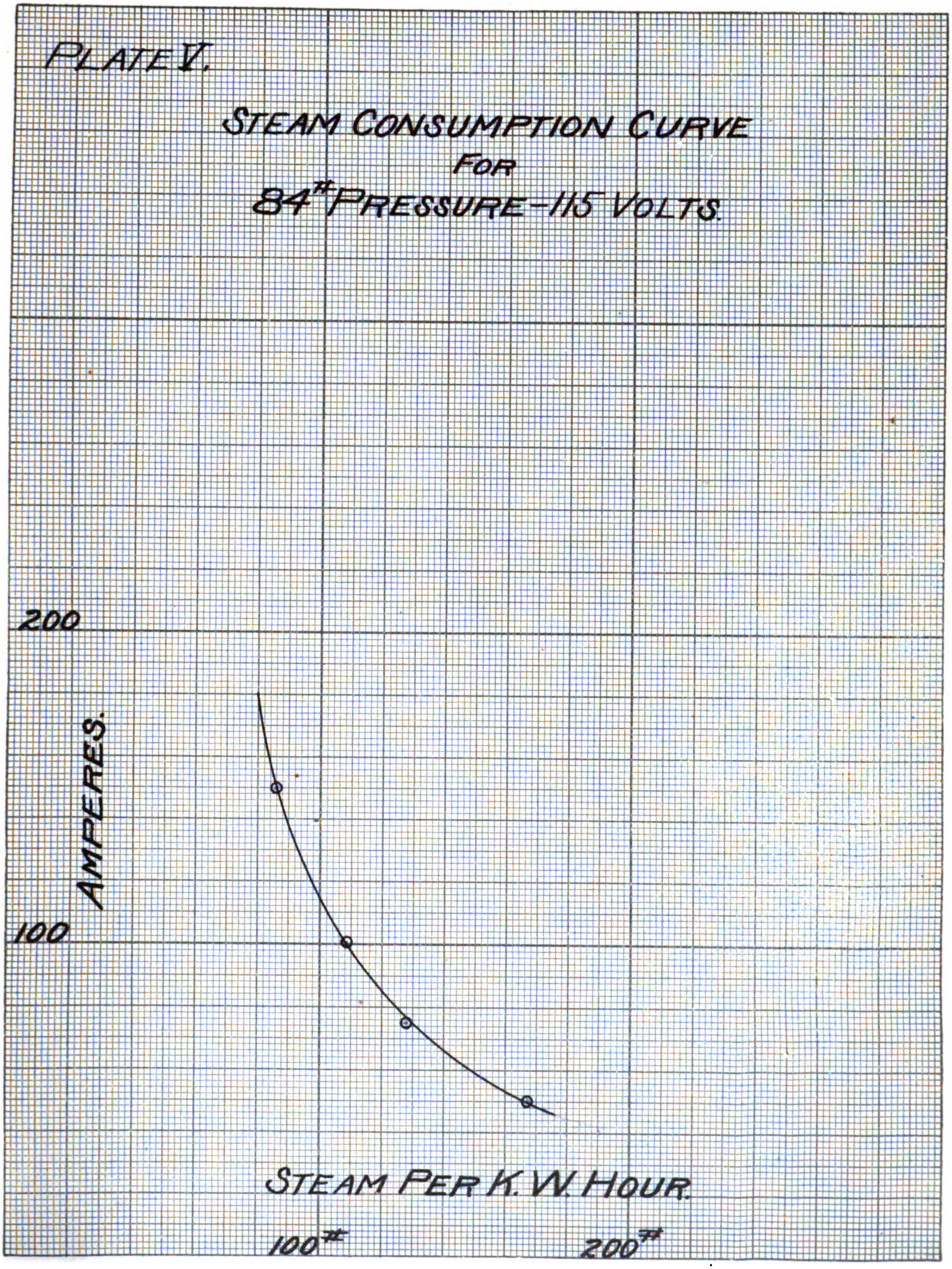
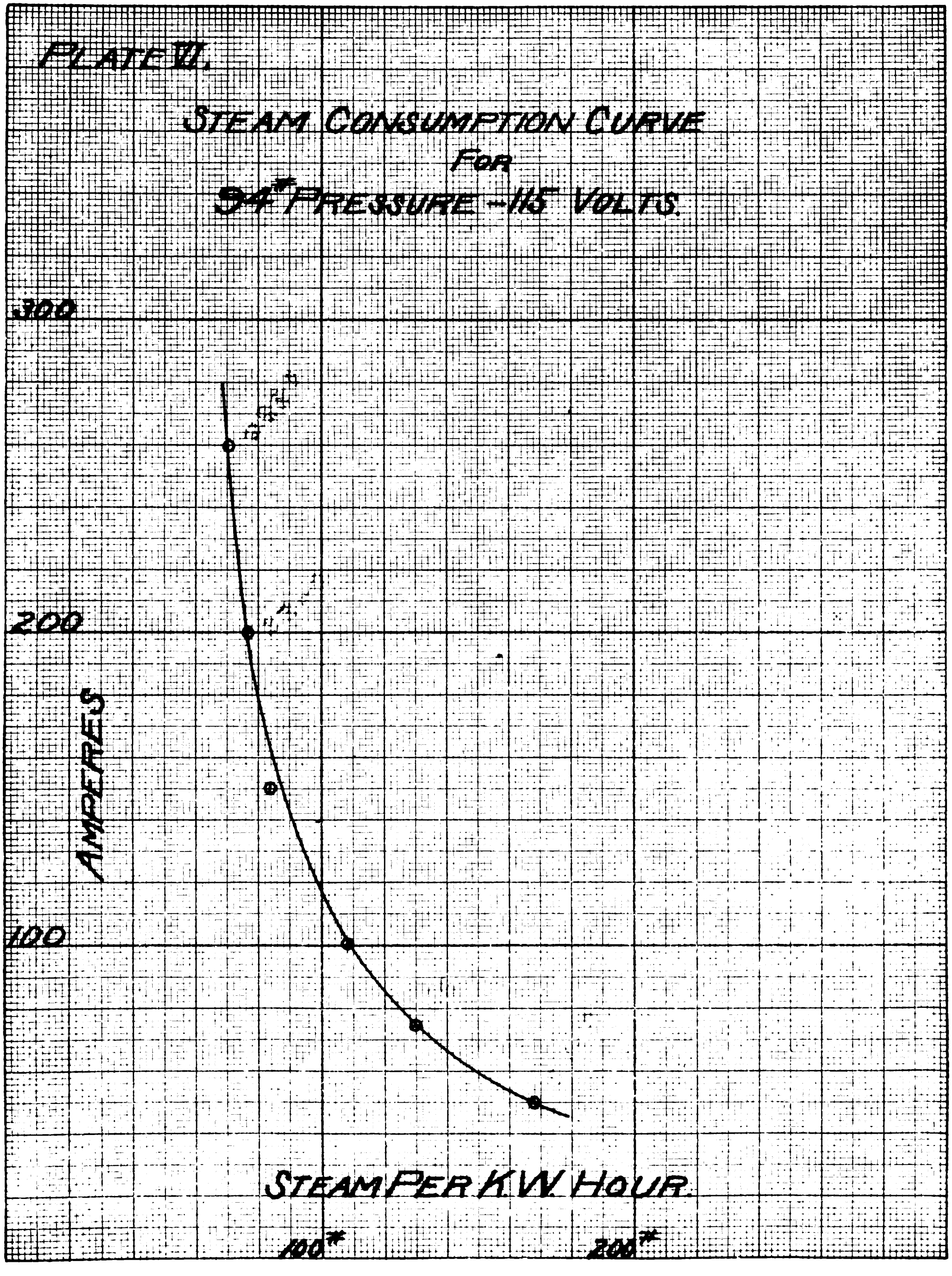


PLATE V.

STEAM CONSUMPTION CURVE
FOR
84# PRESSURE—115 VOLTS.

PLATE VI.

STEAM CONSUMPTION CURVE FOR 94# PRESSURE—115 VOLTS.



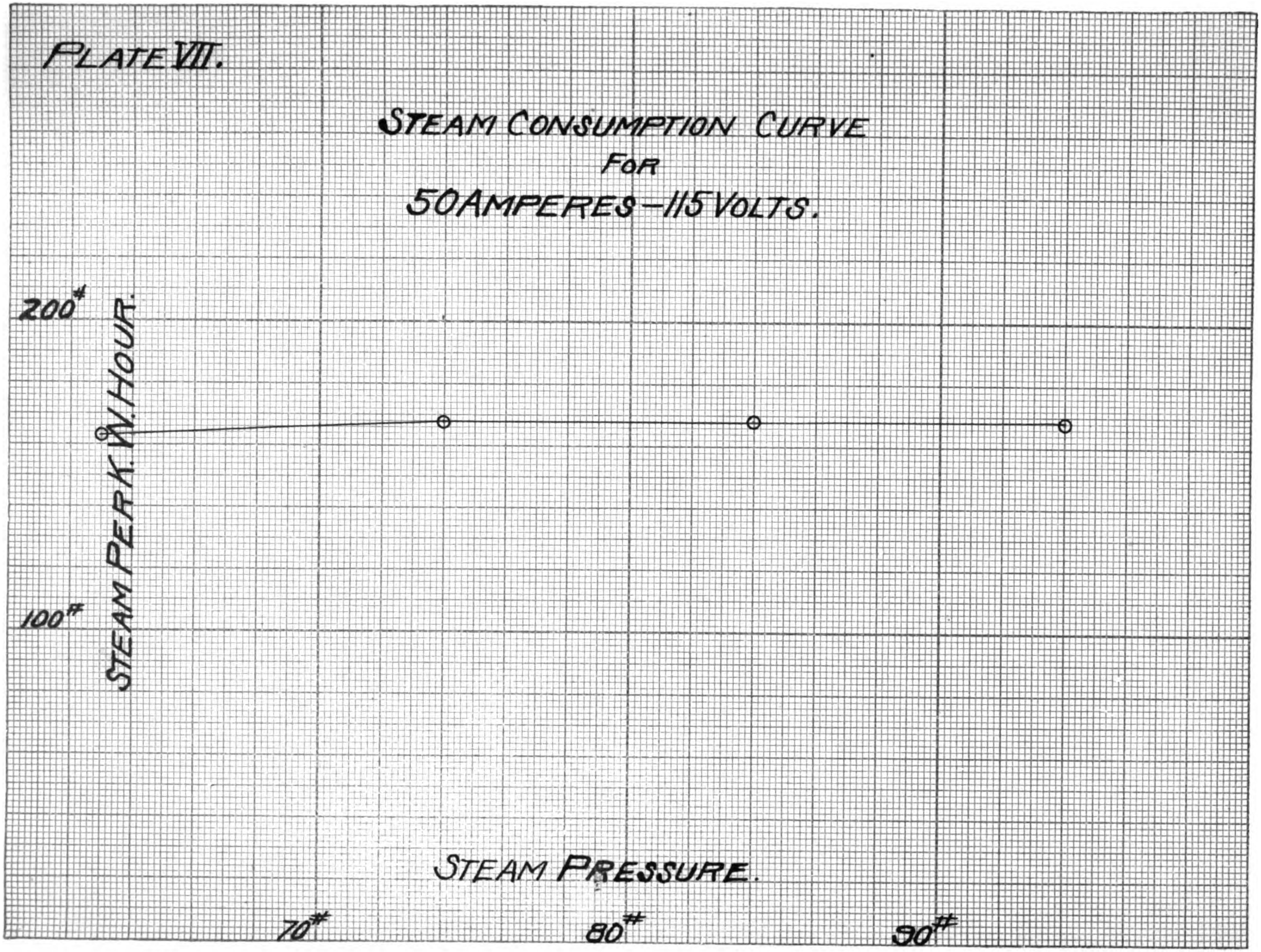


PLATE VII.

STEAM CONSUMPTION CURVE
FOR
50 AMPERES—115 VOLTS.

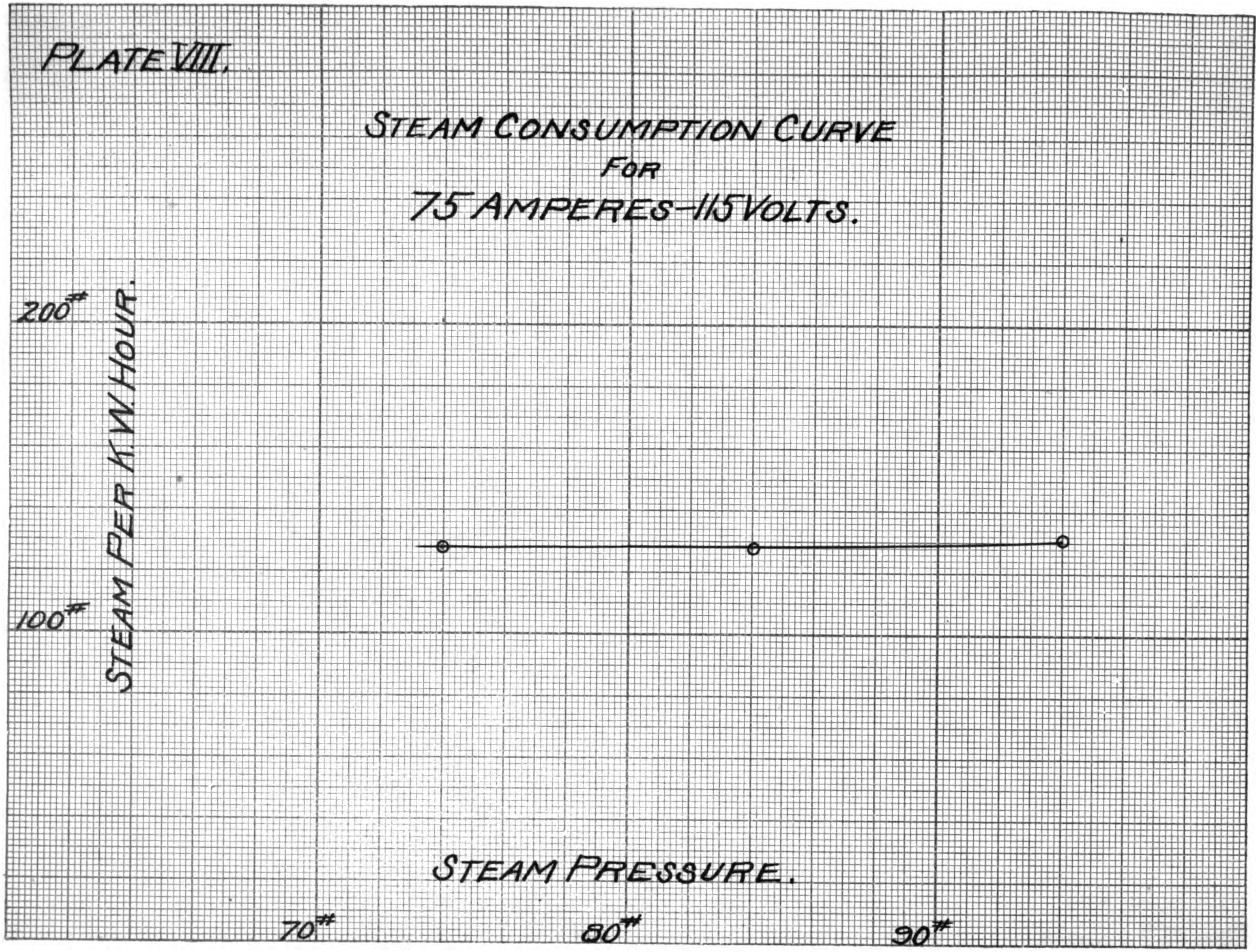


PLATE VIII.

STEAM CONSUMPTION CURVE
FOR
75 AMPERES–115 VOLTS.

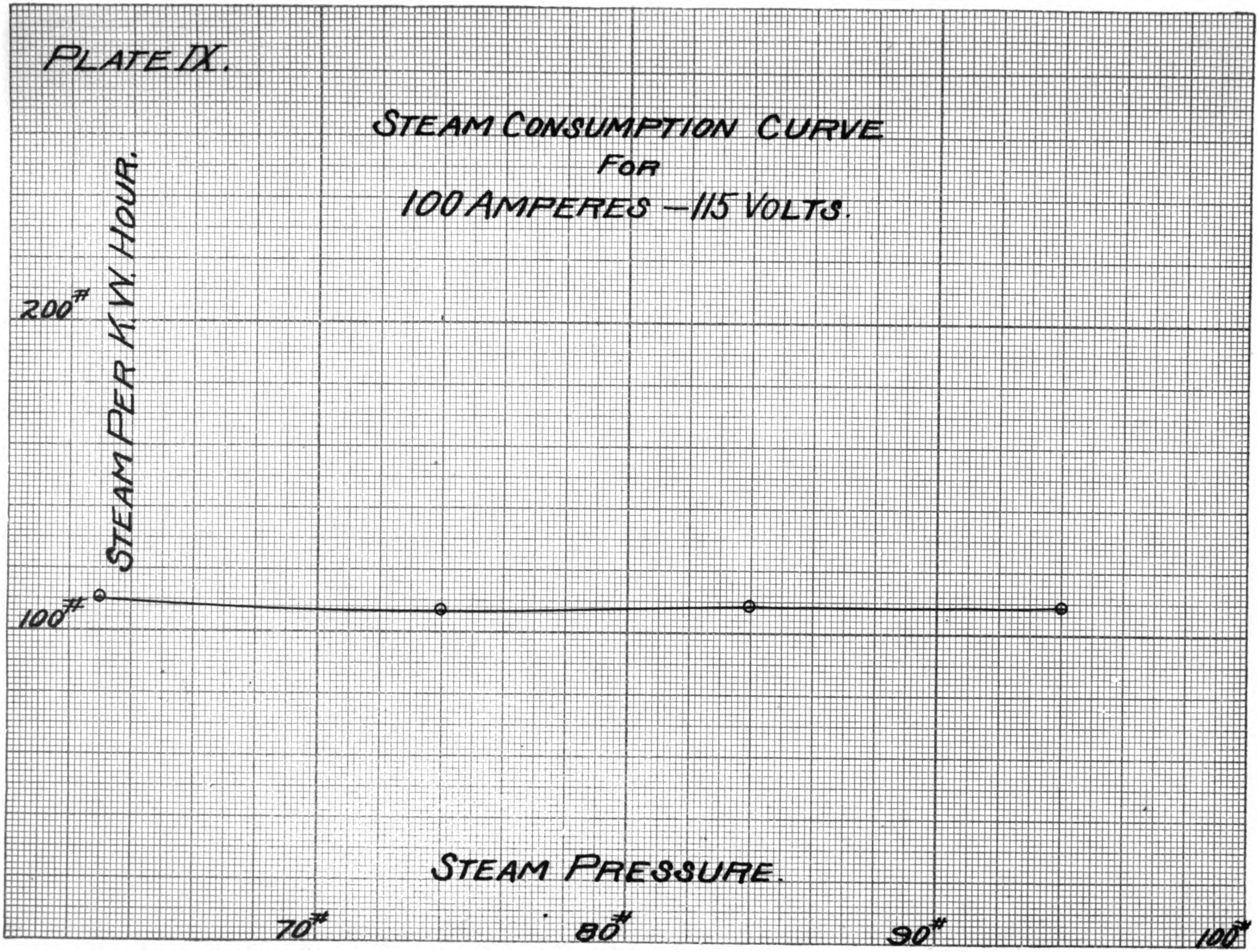


PLATE IX.

STEAM CONSUMPTION CURVE
FOR
100 AMPERES — 115 VOLTS.

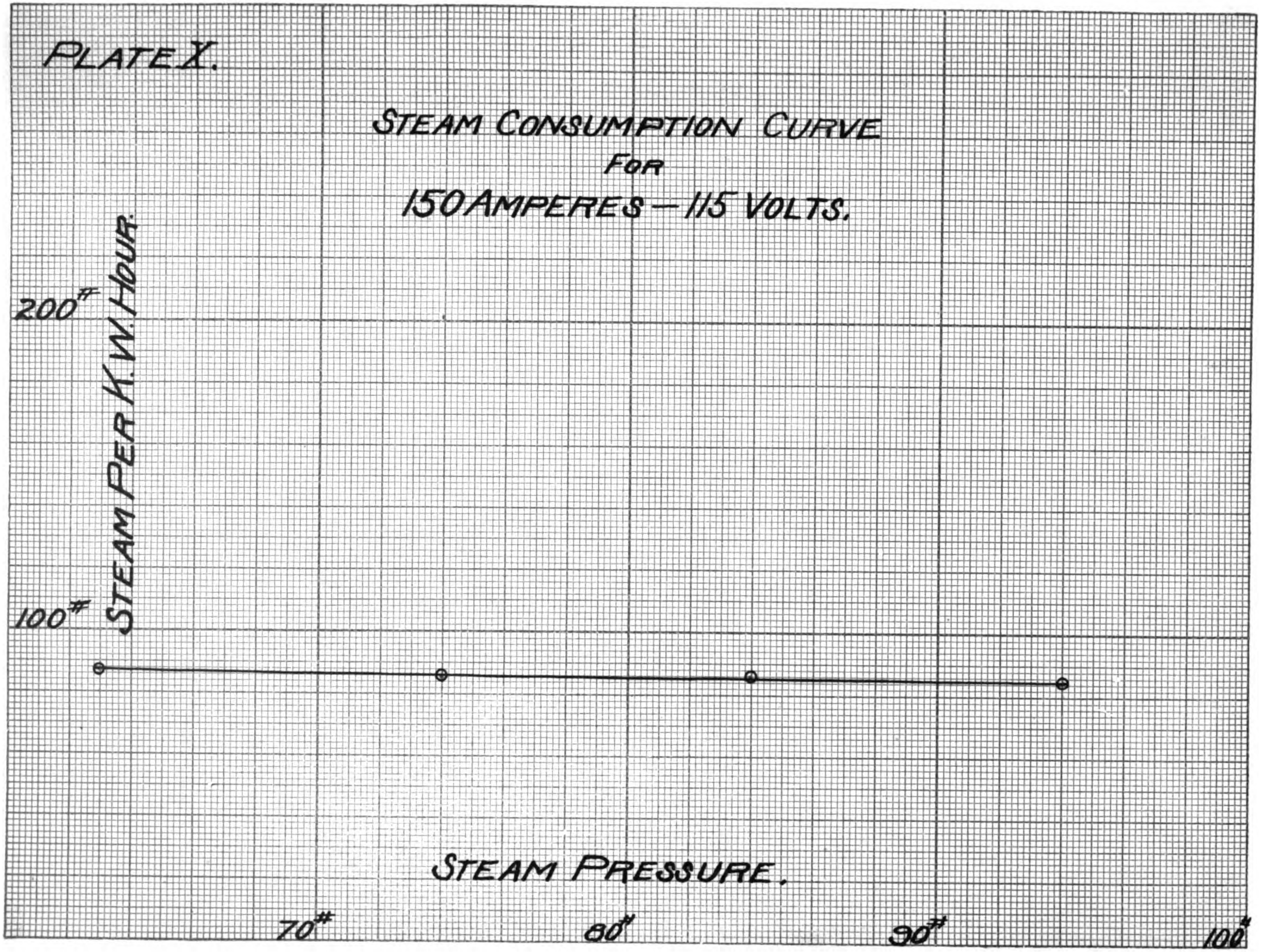
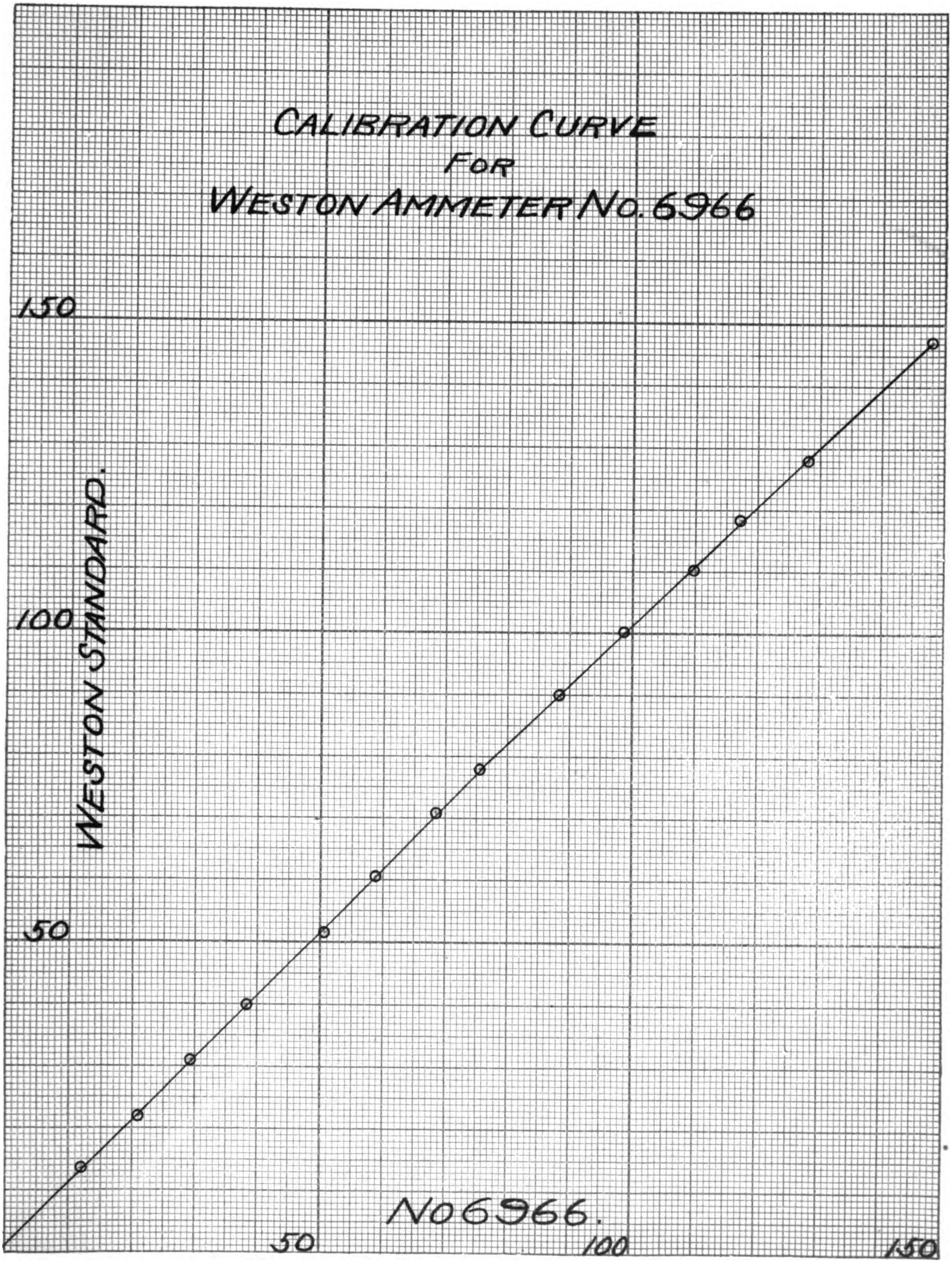
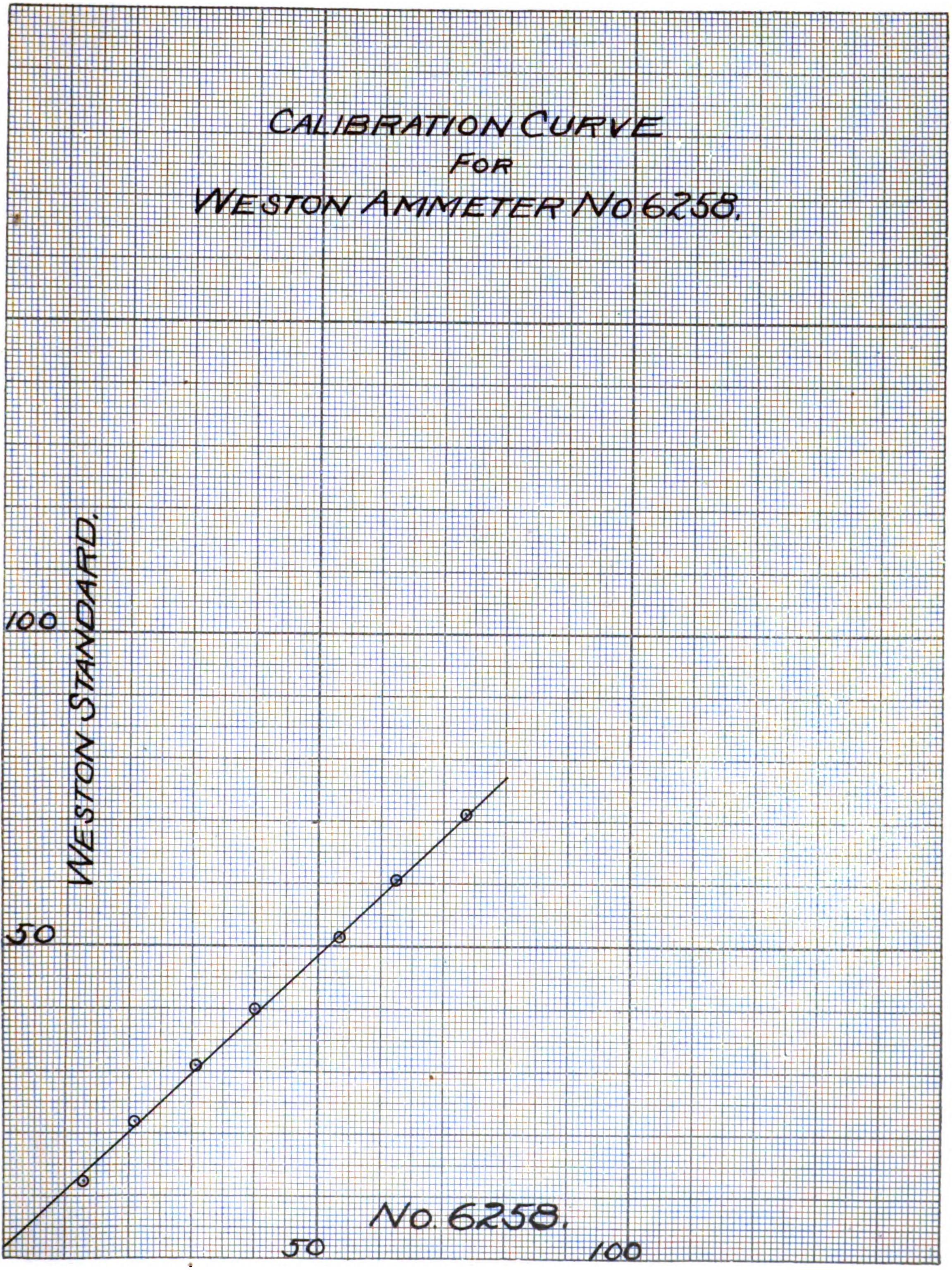


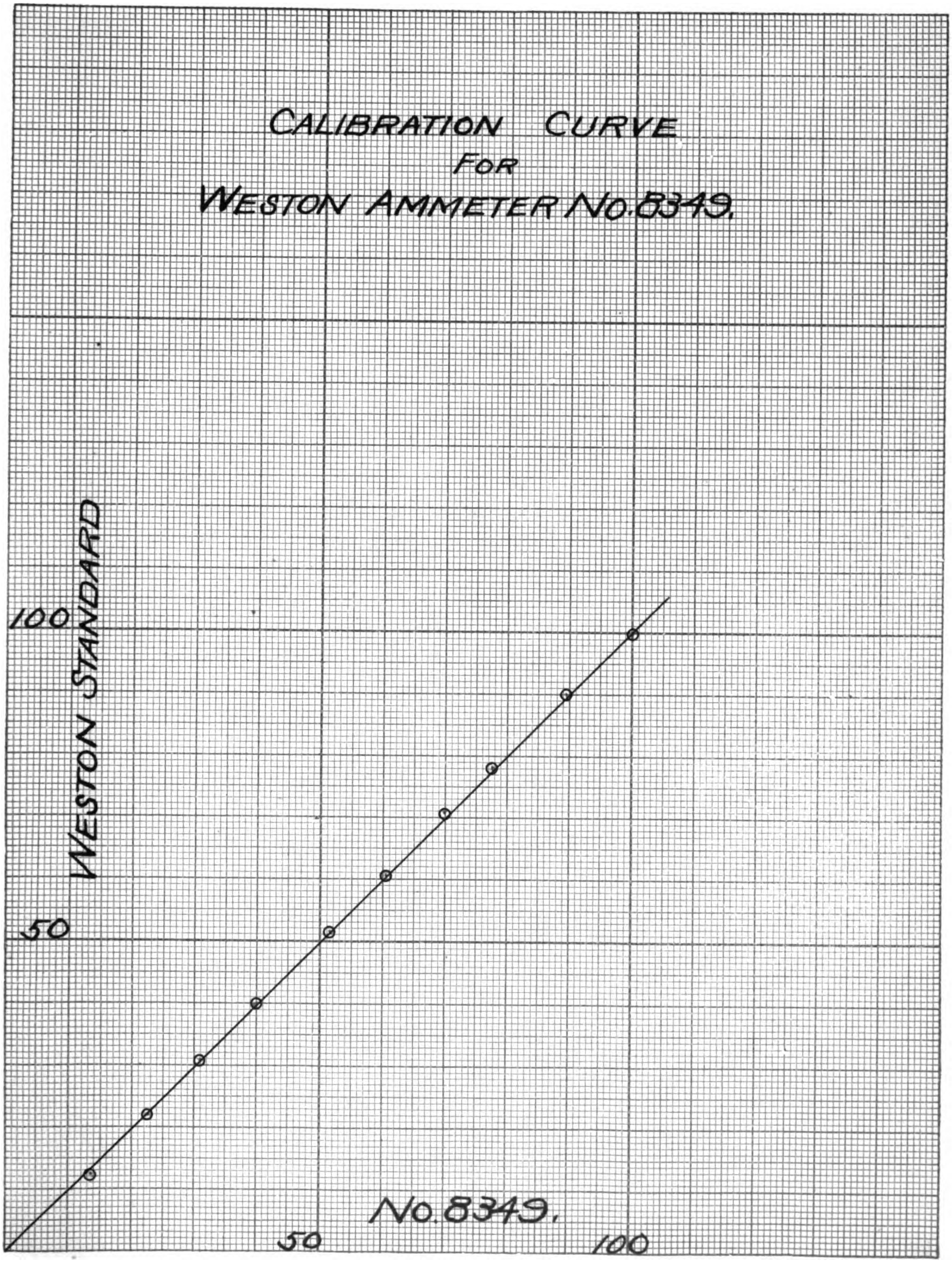
PLATE X.

STEAM CONSUMPTION CURVE
FOR
150 AMPERES — 115 VOLTS.

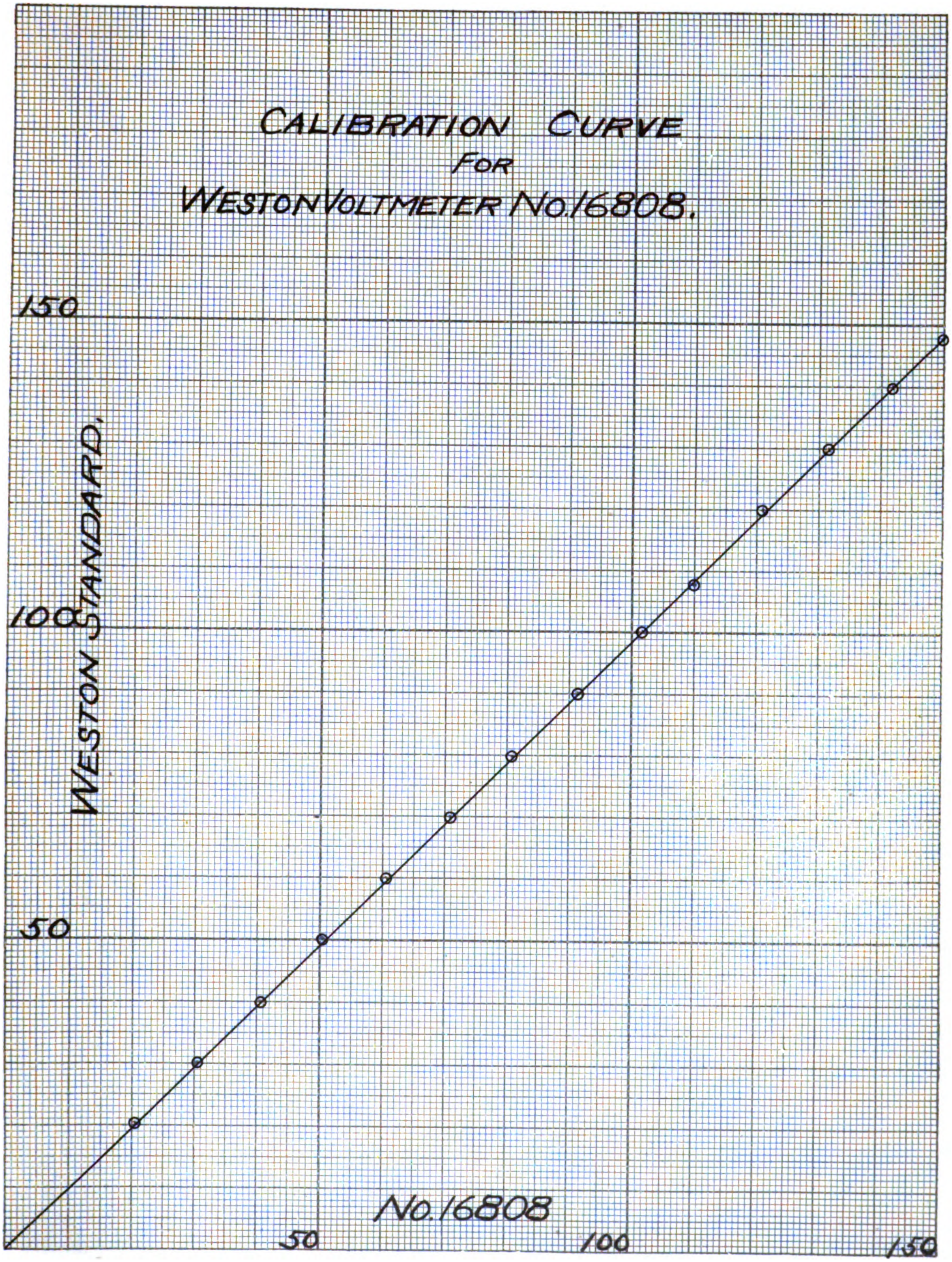

CALIBRATION CURVE
FOR
WESTON AMMETER NO. 6966
150
100
50
WESTON STANDARD.
NO 6966.
50
100
150



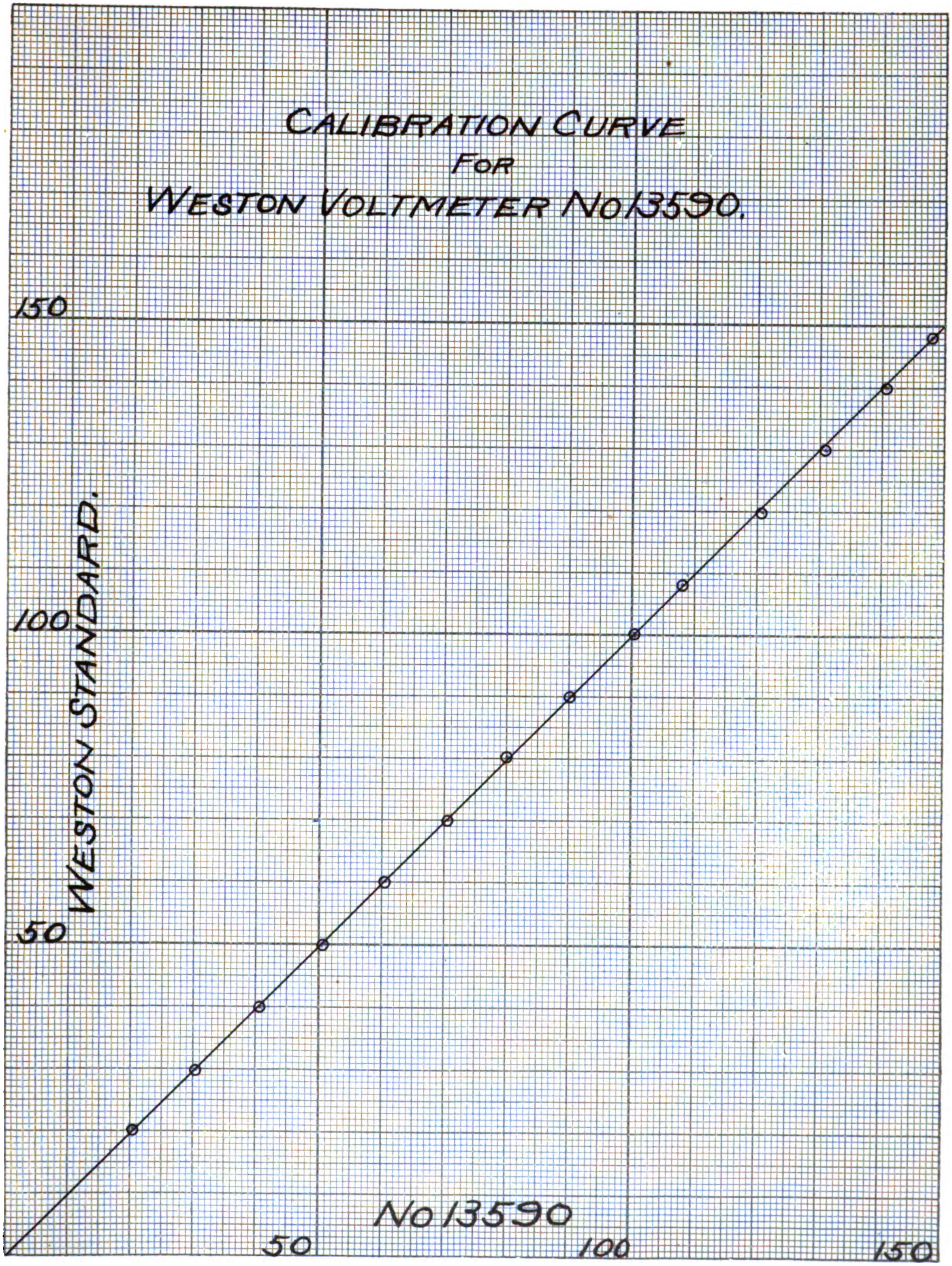
CALIBRATION CURVE
FOR
WESTON AMMETER No 6258.

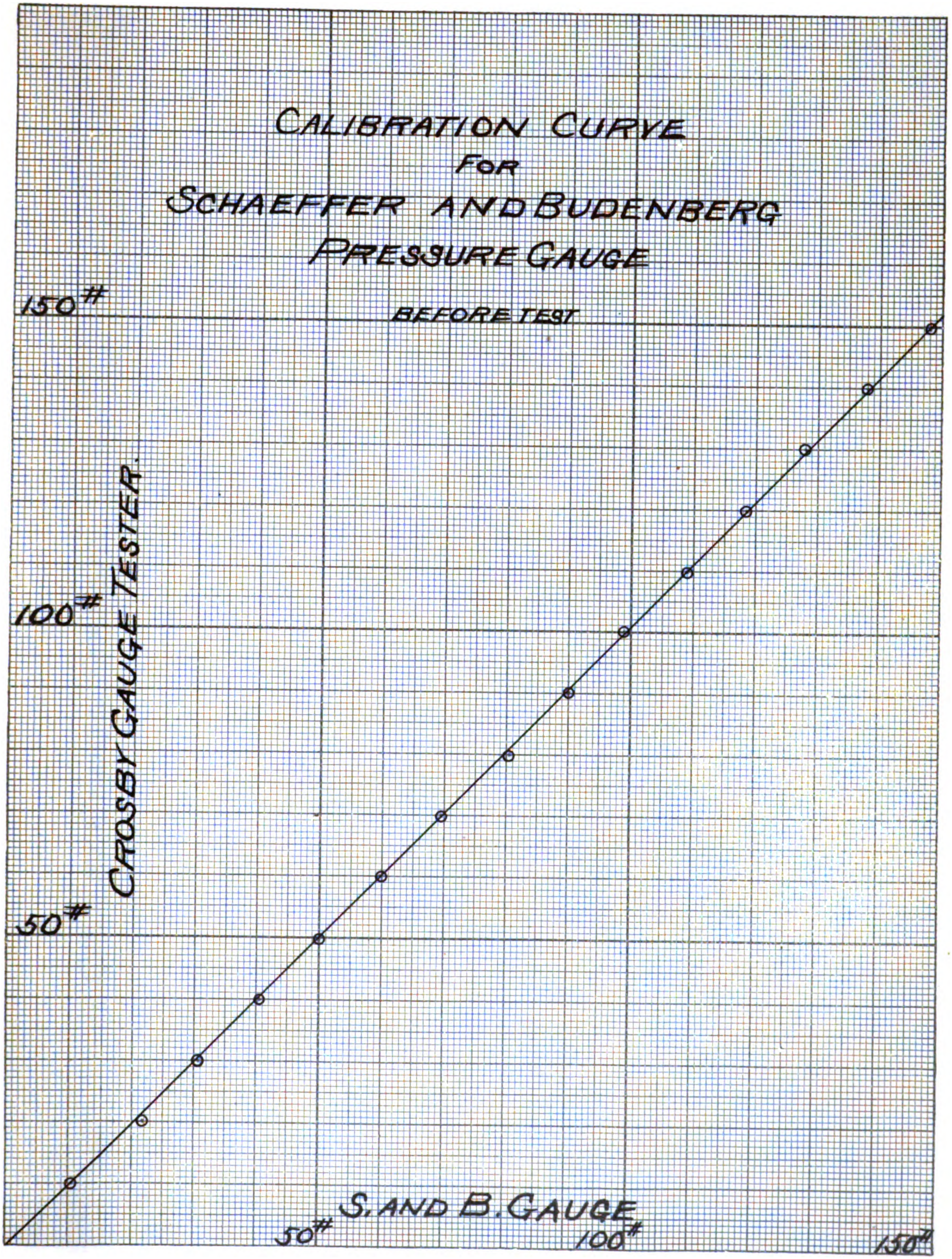


CALIBRATION CURVE
FOR
WESTON AMMETER NO. 8349.


CALIBRATION CURVE
FOR
WESTON VOLTMETER No. 16808.
150
100
50
WESTON STANDARD.
No. 16808
50
100
150

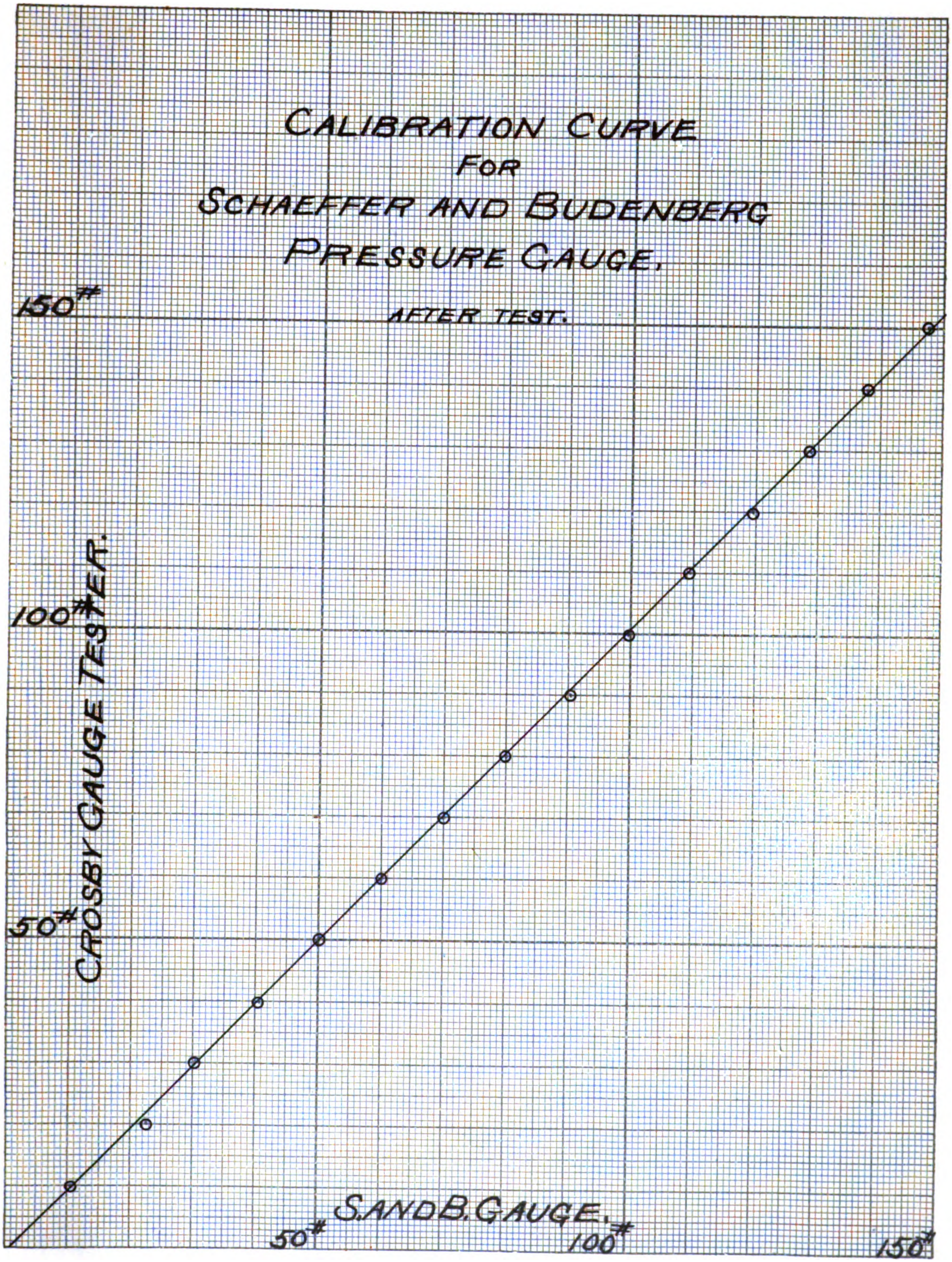
CALIBRATION CURVE
FOR
WESTON VOLTMETER NO 13590.

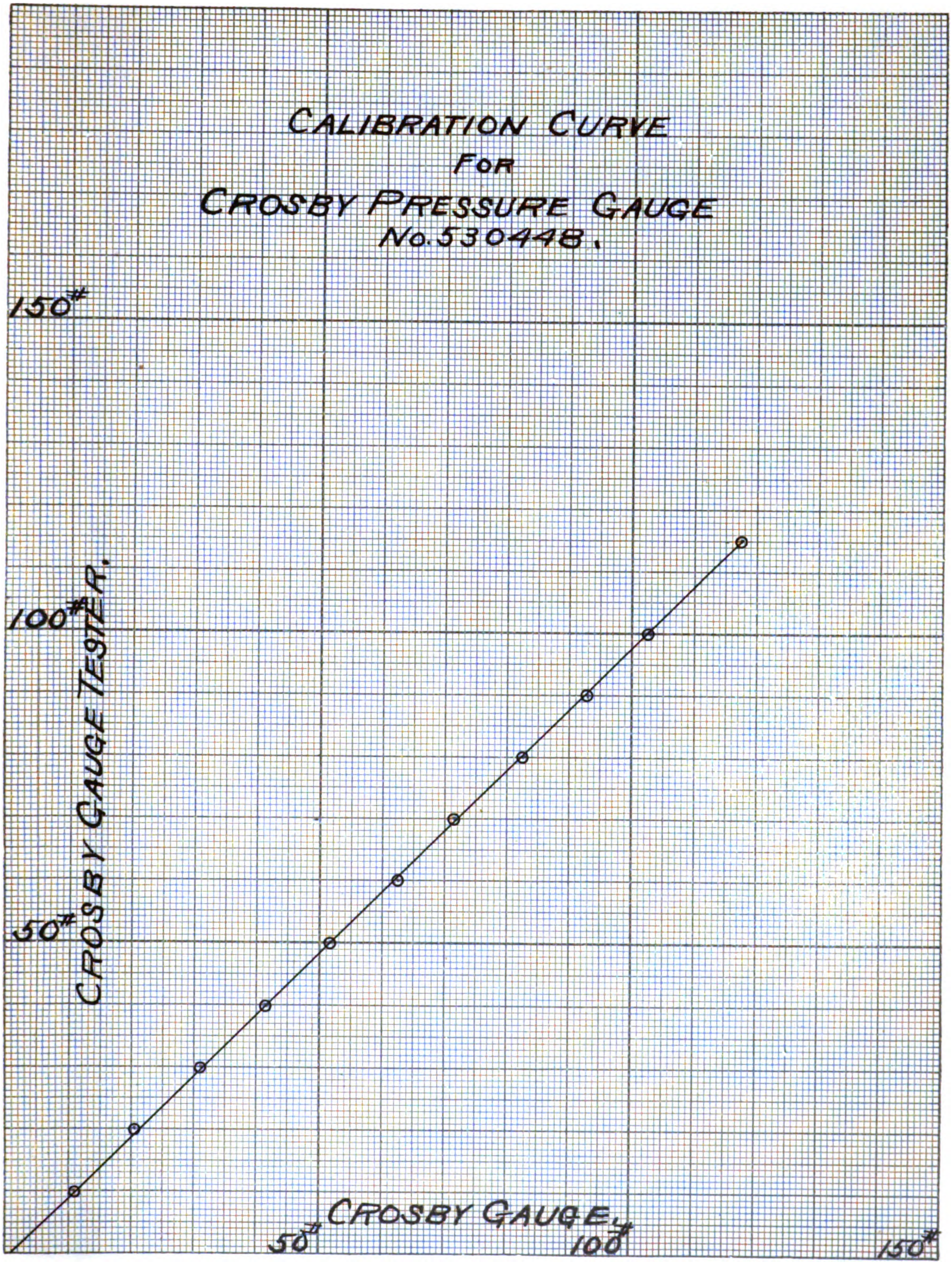




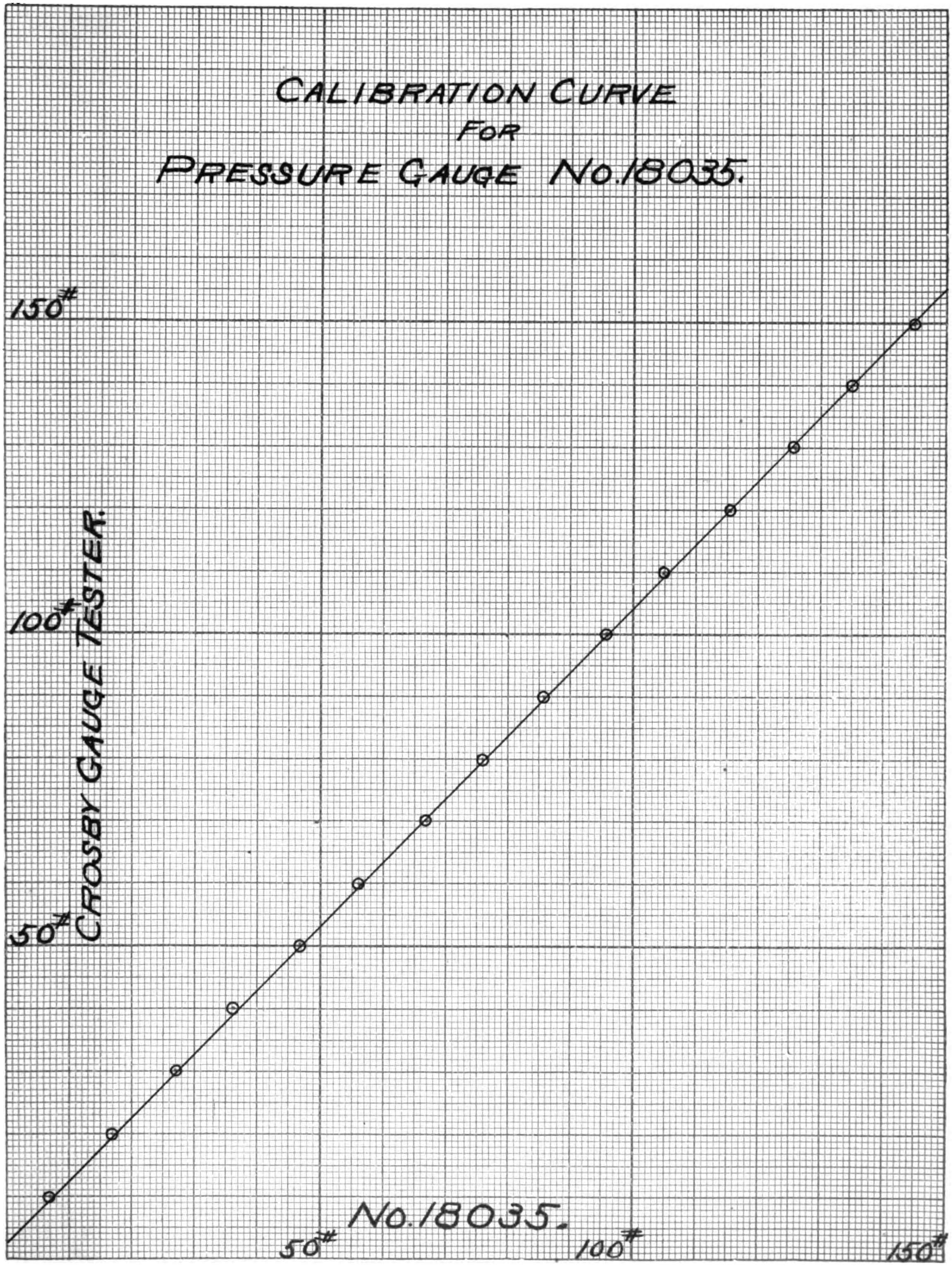
CALIBRATION CURVE
FOR
SCHAEFFER AND BUDENBERG
PRESSURE GAUGE

BEFORE TEST


CALIBRATION CURVE
FOR
SCHAEFFER AND BUDENBERG
PRESSURE GAUGE.
AFTER TEST.
150#
100#
50#
CROSBY GAUGE TESTER.
S.AND B. GAUGE.
50#
100#
150#



CALIBRATION CURVE
FOR
CROSBY PRESSURE GAUGE
No. 530448.


CALIBRATION CURVE
FOR
PRESSURE GAUGE No.18035.
150#
100#
50#
CROSBY GAUGE TESTER.
No.18035.
50#
100#
150#

4
3
3
3
3
35
34
33
32

TEST OF BATTERY EQUIPMENT

The test of this equipment was made on trains numbers 47 and 48 running between Chicago and Minneapolis. The equipment consisted of one battery of 48 cells of 160 ampere hour capacity of the American Battery Co. on each car. These batteries supply the line directly through switches placed conveniently in closets in each car, which are thrown in or out as desired by the porter. The equipment is extremely simple as no regulating device or complicated mechanism is in the circuit.

The OPERATION of the batteries is as follows:- a charge is given the batteries during the day at Minneapolis, which is followed by the discharge during that night in the run to Chicago; at Chicago the batteries are again charged and are discharged on the return trip to Minneapolis.

The charging at Minneapolis is accomplished by means of a Curtis Turbo Generator Set of the type and capacity used in the baggage car equipments of this road, described above in the first test. The turbo generator set is installed with a boiler of sufficient capacity in a frame building, beside

which the train of cars stand during the day. Boiler pressure is maintained at 120 pounds and the turbine operates very satisfactorily, requiring very little attention on the part of the attendant. The current leads pass from the generator to a switchboard containing switches, ammeters and voltmeters, from which they pass to a pole line beside the track. At the car desired, a tap connected to a Gibbs connector leads off, and in charging is connected with the battery circuit. As soon as the train is backed into the track, the proper connections are made and the charge begins. The charge at Minneapolis is usually started within a half hour after the arrival of the train at the depot. Barring a shut down from twelve to one at noon, the batteries are charged continuously from eight-thirty in the morning until five-thirty in the afternoon, at about 110 volts.

The charge at Chicago is accomplished similarly except that the charging unit is a dynamo with belt connections to a vertical steam engine, in what is known as the 12th Street charging station.

METHOD OF TESTING

In making the test of this equipment switches were placed in the battery circuits of each car by means of which an ammeter could be plugged in and the current of the line sent through it without interruption of the service. These switches were placed on each car, in the closet containing the line and light switchboard. Voltage readings were obtained by placing contact points connected directly to the voltmeter on the two lines of the circuit. As indicated by the data, readings of the pressure and current were taken at regular intervals throughout three charges and discharges of the batteries. The charges were made in the yards at Chicago and Minneapolis and the discharges on the runs between Chicago and Minneapolis. The separate charges and discharges of the four cars tested are plainly indicated on Plates XI - XVIII which follow.

DISCUSSION OF RESULTS

The results of the BATTERY TEST indicate that the batteries are in good condition since their average efficiency figures out 49 %. The efficiency of the batteries on Chair car 4151 is high, due to some unexplainable cause. As seen in the curve of battery charge on Plate XIV the charge on the 12th was very irregular - there being but a small input until four in the afternoon, when the input suddenly increased from a value very near zero to 4 K. W. This erratic action is difficult to explain and leads to the conclusion that a connection was probably loose during the day and was tightened at the time the increase in input occurred. The charges on the 13th and 14th were normal and the charge on the 12th raises the efficiency somewhat.

The data indicates that the batteries were not heavily taxed at any time during the trips and the curves show that the voltage was up fairly high at the end of the discharges.

A point of importance is the extreme simplicity of the system - there being no complicated mechanism, and no attendant is required on the train to keep the service in order.

DATA OF BATTERY TEST

TESTS ON TRAINS 47 AND 48

RUNNING BETWEEN CHICAGO AND MINNEAPOLIS

CHAIR CAR NUMBER 501

Time P. M.	Amperes	Volts	Output K. W.	Time A. M.	Amperes	Volts	Input K. W.	Specific Gravity
Discharge May 11, 1906				Charge May 12, 1906				
Chicago to Minneapolis				Yards at Minneapolis				
6:30				8:30				
7:00	5.6	97.0	.543	9:30	18.6	105.0	1.950	
7:30	11.8	95.0	1.120	9:45	18.8	108.0	2.050	
8:15	12.4	93.5	1.160	10:30	-	-	-	1195
8:30	12.4	93.0	1.150	11:15	20.0	113.0	2.260	
9:00	6.9	90.0	.621	11:30	14.8	113.0	1.675	
9:30	6.9	90.0	.621	12:00	14.8	113.0	1.675	
10:00	5.3	89.0	.472	12:00 - 1:00 shut down.				
10:30	5.3	89.0	.472	12:45	-	-	-	1200
11:00	4.0	87.0	.438	1:00	7.2	115.0	.830	
11:30	3.0	89.0	.257	1:30	7.2	115.0	.830	
12:00	3.4	89.0	.312	2:00	6.9	116.0	.800	
12:45	2.5	89.0	.222	2:30	8.6	118.0	1.012	
1:15	1.5	89.0	.133	3:00	13.2	121.0	1.600	
2:00	2.1	88.0	.185	3:30	17.8	123.0	2.190	
2:30	2.2	88.0	.193	4:15	12.5	121.0	1.515	
3:15	2.7	89.0	.241	4:30	13.0	121.0	1.575	
3:30	3.0	88.0	.264	5:15	12.9	121.0	1.565	
4:15	4.4	87.0	.387	5:30	-	-	-	1216
4:30	4.8	87.0	.422					
5:15	4.4	86.0	.378					
5:30	4.8	87.0	.422					
6:15	3.2	87.0	.281					
6:30	3.0	86.5	.259					
7:00	4.0	88.0	.510					
7:30	5.8	87.0	.504					

Charge - 8 hours.

Average K. W. - 1.48

K. W. hour input - 11.85

Discharge - 13 hours.

Average K. W. - .4

K. W. hour output - 5.2

Discharge May 12, 1906

Minneapolis to Chicago

7:30			
7:56	13.6	94.0	1.270
9:00	9.0	92.0	.828
9:30	8.4	91.5	.769
10:00	4.8	91.5	.438
10:30	4.5	91.5	.411
11:00	4.2	92.0	.586
12:00	1.0	92.0	.092
2:00	.3	93.0	.028
3:00	1.3	92.0	.119
3:30	1.5	92.0	.138
4:00	2.0	92.0	.184
5:15	4.4	91.0	.400
5:55	3,8	90.0	.342
6:30	3.8	90.0	.342

Discharge - 11 hours.

Average K. W. - .4

K. W. hour output - 4.4

Charge May 13, 1906

Yards at Chicago

9:50	-	-	-	1195
10:00				
10:30	24.2	108.0	2.615	
11:15	15.0	109.0	1.635	
11:45	15.0	110.0	1.650	
12:45	12.5	115.0	1.435	
1:00	11.0	116.0	1.275	
1:45	12.5	123.0	1.535	
2:30	11.5	122.0	1.450	
3:30	22.0	128.0	2.820	1217
4:15	23.5	128.0	3.000	
4:30	23.5	128.0	3.000	

Charge - 6 houre, 40 minutes.

Average K. W. - 1.95

K. W. hour input - 13

Discharge May 13, 1906

Chicago to Minneapolis

6:05			
6:30	13.6	96.0	1.305
7:00	8.0	95.0	.760
8:00	9.0	92.0	.828
9:00	9.6	89.0	.855
9:45	12.2	86.0	1.050
11:00	10.5	85.5	.945

Charge May 14, 1906

Yards at Minneapolis

8:30			
9:00	27.0	103.0	2.780
10:15	21.3	106.0	2.260
11:00	17.6	107.0	1.885
11:15	15.7	107.0	1.680
11:45	19.7	110.0	2.170

12:00 - 1:00 shut down.

12:45	5.3	85.5	.586
2:45	7.0	83.5	.584
3:00	4.7	84.0	.394
4:30	1.5	81.0	.122
5:00	3.8	82.0	.312
5:45	4.0	82.0	.328
6:00	4.0	82.0	.328

Discharge - 11 hours, 55 minutes.

Average K. W. -.47

K. W. hour output - 8.34

1:00	14.0	108.0	1.510
1:40	9.0	107.0	.963
2:30	10.6	110.0	1.275
3:30	7.8	111.0	.865
4:30	13.2	119.0	1.570
5:15	9.5	125.0	1.189
5:30	9.5	125.0	1.189

Charge - 8 hours.

Average K. W.- 1.72

K. W. hours input - 13.75

Average output - 5.98 K. W. hours.

Average input - 12.86 K. W. hours.

Efficiency - 46.5 %

SLEEPER PANTHEON

Time P. M.	Amperes	Volts	Output K. W.	Time A. M.	Amperes	Volts	Input K. W.	Specific Gravity
Discharge May 11, 1906				Charge May 12, 1906				
Chicago to Minneapolis				Yards at Minneapolis				
6:30				8:30				
7:00	11.0	95.0	1.042	9:30	20.4	96.0	1.960	
7:30	11.0	95.0	1.042	10:15	-	-	-	1160
8:00	18.6	94.0	1.750	10:45	21.0	109.0	2.290	
8:30	15.8	93.0	1.470	11:00	27.0	113.5	3.070	
9:15	13.8	92.0	1.270	11:30	23.2	112.5	2.610	
9:30	10.8	91.0	.985	12:00	23.2	113.0	2.630	
10:00	6.7	90.0	.603	12:00 - 1:00 shut down.				
10:30	6.9	88.0	.870	12:45	-	-	-	1185
11:00	8.4	87.0	.741	1:30	14.2	113.0	1.610	
11:30	4.3	89.0	.385	2:00	14.8	116.0	1.720	
12:00	4.7	89.0	.418	2:30	11.0	120.0	1.320	
12:45	4.3	88.5	.381	3:00	14.4	124.5	1.790	
1:15	3.4	89.0	.303	3:30	17.0	126.0	2.140	
2:00	3.4	88.0	.299	4:15	8.8	122.0	1.070	
2:30	3.3	88.0	.291	4:30	11.6	123.0	1.430	
3:15	2.8	88.0	.247	5:15	10.8	123.0	1.330	
3:30	2.8	88.0	.247	5:30	10.8	123.0	1.330	1211
4:15	2.5	87.0	.217					
4:30	2.3	86.5	.199					
5:00	1.7	86.5	.145					
5:30	1.8	86.0	.155					
6:15	1.0	86.0	.086					
6:30	0.9	86.0	.072					
7:00	0.4	87.0	.034					
7:30	0.8	85.0	.068					
Discharge - 13 hours.				Charge - 8 hours.				
Average K. W. - .57 .				Average K. W. - 1.92				
K. W. hour output - .74				K. W. input - 15.35				

Discharge May 12, 1906

Minneapolis to Chicago

7:30			
8:00	19.2	96.0	1.941
9:00	17.4	95.0	1.655
9:30	13.2	95.0	1.255
10:00	9.0	95.0	.855
10:30	7.0	95.0	.655
11:00	5.9	95.0	.561
12:00	4.3	95.0	.409
2:00	3.3	92.5	.305
3:00	4.1	92.0	.377
4:00	3.4	92.0	.313
5:00	3.3	92.0	.303
6:00	2.1	93.0	.196
6:30	2.1	93.0	.196

Discharge - 11 hours.

Average K. W. - .67

K. W. hour output - 7.36

Charge May 13, 1906

Yards at Chicago

9:30	-	-	- -	1150
10:00				
10:30	20.6	107.0	2.210	
11:15	18.5	108.0	2.000	
1:15	25.5	115.0	2.930	
1:45	18.0	122.0	2.200	
2:30	16.0	124.5	1.995	
3:30	16.5	127.5	2.105	1212
4:30	15.0	127.5	1.195	

Charge - 6 hours, 40 minutes.

Average K. W. - 2.2

K. W. input - 14.68

Discharge May 13, 1906

Chicago to Minneapolis

6:30			1.082
9:00	12.3	88.0	1.272
9:40	14.8	86.0	.705
11:00	8.2	86.0	.310
12:45	3.6	86.0	.168
2:30	2.0	84.0	.133
3:00	1.6	83.0	.123
4:30	1.5	82.0	.082
5:45	1.0	82.0	.066
6:30	0.8	83.0	.066

Discharge - 12 hours.

Average K. W. - .51

K. W. hour output - 6.12

Charge May 14, 1906

Yards at Minneapolis

8:30			
9:00	21.0	106.0	2.230
9:15	19.2	108.0	2.070
11:00	19.5	110.0	2.150
11:45	25.5	114.0	2.910
12:00 - 1:00 shut down.			
1:00	17.8	110.0	1.960
2:30	11.2	111.0	1.240
3:30	10.4	114.0	1.300
5:15	18.2	127.5	2.320
5:30	18.2	127.5	2.320

Charge - 8 hours.

Average K. W. - 1.97

K. W. hour input.- 15.72

Average output -	Average input -
6.96 K. W. hours.	15.25 K. W. hours.

Efficiency - 45.0 %

SLEEPER APOLLO

Time P. M.	Amperes	Volts	Output K. W.	Time A. M.	Amperes	Volts	Input K. W.	Specific Gravity
Discharge May 11, 1906				Charge May 12, 1906				
Chicago to Minneapolis				Yards at Minneapolis				
6:30				8:30				
7:00	7.4	97.0	.717	10:15	-	-	-	1213
7:30	14.8	95.0	1.405	10:45	30.0	110.0	3.300	
8:30	15.7	94.0	1.475	11:00	35.0	112.0	3.920	
9:00	20.0	92.0	1.840	11:30	24.0	112.0	2.690	
9:45	20.0	85.0	1.710	12:00	24.0	112.0	2.690	
10:00	16.6	81.0	1.345	12:00 - 1:00 shut down.				
10:30	17.5	78.0	1.365	12:45	-	-	-	1235
11:00	10.3	87.0	.896	1:00	19.5	114.0	2.320	
11:30	6.0	90.0	.540	2:00	19.5	118.0	2.300	
12:00	5.8	88.0	.510	2:30	13.4	120.0	1.610	
12:40	4.8	89.0	.427	3:00	16.0	123.0	1.965	
1:15	3.7	98.0	.329	3:30	17.0	126.0	2.140	
2:00	3.7	88.0	.325	4:00	17.0	120.0	2.040	
2:30	3.8	90.0	.342	4:30	9.7	122.0	1.182	
3:00	3.2	88.0	.281	5:15	9.4	122.0	1.145	
3:30	3.0	88.0	.264	5:30	9.4	122.0	1.145	1252
4:00	2.0	88.0	.176					
4:30	2.0	87.0	.174					
5:00	1.8	87.0	.156					
5:30	1.5	86.0	.129					
6:00	1.4	85.0	.119					
6:30	1.2	86.0	.103					
7:25	1.4	85.0	.119					
7:30	1.4	85.0	.119					
Discharge - 13 hours.				Charge - 8 hours.				
Average K. W. - .67				Average K. W. - 2154				
K. W. hour output - 8.72				K. W. hour input - 20.3				

Discharge May 12, 1906

Minneapolis to Chicago

7:30			
8:00	14.5	97.0	1.405
9:00	14.5	96.5	1.400
9:30	7.4	96.0	.710
10:00	7.4	95.0	.704
10:30	2.5	97.0	.242
11:00	2.6	97.0	.252
12:00	2.5	96.0	.240
2:00	1.5	96.0	.144
3:00	1.5	96.0	.144
4:30	13.9	92.0	1.280
4:50	13.5	92.0	1.241

Discharge – 9 hours, 20 minutes.

Average K. W. – .6

K. W. hour output – 5.6

Charge May 13, 1906

Yards at Chicago

9:50	– –	–	–	1240
10:00				
10:45	23.0	109.0	2.510	
11:00	18.0	109.0	1.965	
11:30	23.0	100.5	2.310	
12:00	23.0	113.5	2.610	
1:00	25.0	118.0	2.950	
1:45	20.0	124.0	2.480	
2:30	21.0	126.5	2.660	
3:00	24.5	128.5	3.150	1265
4:30	22.5	128.5	2.890	

Charge – 6 hours, 40 minutes.

Average K. W. – 2.5

K. W. hour input – 16.65

Discharge May 13, 1906

Chicago to Minneapolis

6:30			
7:00	10.0	95.0	.950
8:00	11.4	95.0	1.082
9:00	8.2	95.0	.778
9:45	8.5	95.0	.808
11:00	7.8	94.5	.736
12:45	3.0	94.0	.282
2:30	3.0	93.5	.283
3:15	3.0	93.5	.283
4:15	3.0	93.0	.279
5:30	3.0	93.0	.279

Charge May 14, 1906

Yards at Minneapolis

8:30			
9:00	13.5	105.0	1.415
10:20	12.1	105.0	1.270
11:15	14.2	107.0	1.520
12:00	14.2	107.0	1.520
12:00 – 1:00 shut down.			
1:00	13.5	108.0	1.457
1:45	8.7	108.0	.940
2:30	8.4	110.0	.925
3:15	6.5	112.0	.728
4:30	6.3	120.0	.756
5:15	12.7	125.0	1.585
5:30	12.7	125.0	1.585

Average output - Average input -

8.69 K. W. hours. 17.29 K. W. hours.

Efficiency - 50.3 %

CHAIR CAR NUMBER 4151

Time P. M.	Amperes	Volts	Output K. W.	Time A. M.	Amperes	Volts	Input K. W.	Specific Gravity
Discharge May 11, 1906				Charge May 12, 1906				
Chicago to Minneapolis				Yards at Minneapolis				
6:30				8:30				
7:00	9.0	97.0	.875	9:30	5.0	105.5	.527	
7:30	12.2	97.0	1.182	10:15	-	-	- -	1240
8:00	13.2	96.0	1.268	10:45	0.2	111.0	.022	
8:45	12.0	95.0	1.140	11:00	0.2	113.0	.023	
9:00	12.8	95.0	1.215	11:45	0.2	113.0	.023	
9:45	10.2	95.0	.969	12:00	0.2	114.0	.023	
10:00	6.8	94.0	.639	12:00 - 1:00 shut down.				
10:30	7.0	94.0	.657	12:45	-	-	- -	1246
11:30	13.5	91.0	1.229	1:30	0.2	115.0	.023	
12:00	7.0	93.0	.650	2:00	0.2	115.0	.023	
12:30	7.0	91.0	.636	2:30	0.1	120.0	.012	
1:15	2.6	95.0	.247	3:00	0.1	124.0	.012	
2:00	2.5	95.0	.237	3:45	0.0	127.0	.000	
2:30	2.5	94.0	.235	4:00	35.0	113.0	3.960	
3:00	2.5	94.0	.235	4:30	35.0	117.0	4.690	
3:50	7.0	89.0	.622	5:15	35.0	118.0	4.130	
4:00	2.5	93.0	.232	5:30	35.0	118.0	4.130	1265
4:30	2.5	93.0	.232					
Discharge - 10 hours.				Charge - 8 hours.				
Average K. W. - .73				Average K. W. - .9				
K. W. hour output - 7.3				K. W. hour input - 7.2				

Discharge May 12, 1906

Minneapolis to Chicago

7:30			
8:00	19.0	96.5	1.835
9:00	18.0	96.5	1.740
9:30	14.7	95.0	1.410
10:00	7.0	95.0	.665
10:30	5.0	96.0	.480
11:00	5.2	95.0	.500
12:00	4.3	94.0	.404
3:00	4.3	92.0	.396
4:00	3.8	92.0	.350
5:00	4.0	92.0	.368
6:00	2.8	93.0	.260
6:30	2.8	93.0	.260

Discharge - 11 hours.

Average K. W. - .67

K. W. hour output - 7.36

Charge May 13, 1906

Yards at Chicago

9:50	-	-	- -	1197
10:00	20.9	108.0	2.250	
10:30	20.7	109.0	2.250	
11:15	20.0	111.0	2.220	
11:45	19.5	112.0	2.190	
12:45	18.4	116.0	2.120	
1:00	18.0	118.0	2.120	
1:45	16.7	121.7	2.030	
2:30	18.0	125.0	2.250	
3:00	19.7	127.0	2.500	
3:30	18.5	128.0	2.370	1252
4:30	1615	128.0	2.120	

Charge - 6 hours, 40 minutes.

Average K. W. - 2.2

K. W. hour input - 14.65

Discharge May 13, 1906

Chicago to Minneapolis

6:00			
7:00	23.0	95.5	2.195
8:00	20.8	95.0	1.975
9:00	20.2	89.0	1.799
9:45	13.4	88.0	1.180
10:00	5.6	86.0	.482
12:45	2.2	86.0	.189
2:45	1.7	84.0	.143
3:00	1.6	83.5	.134
4:30	3.0	82.0	.246
5:45	1.5	82.0	.123
6:30	1.0	83.0	.083

Discharge - 12 hours, 30 minutes.

Average K. W. - .8

K. W. hour output - 10.0

Charge May 14, 1906

Yards at Minneapolis

8:30			
9:00	16.2	106.0	1.720
10:15	18.8	107.5	2.020
11:15	19.1	109.0	2.085
12:00	21.5	111.0	2.390
12:00 - 1:00 shut down.			
1:00	17.2	109.0	1.875
1:40	10.3	108.0	1.220
2:30	12.2	110.5	1.390
3:30	12.7	112.0	1.265
4:30	11.8	120.0	1.415
5:15	18.2	126.0	2.280
5:30	18.2	126.0	2.280

Charge - 8 hours.

Average K. W.- 1.99

K. W. hour input - 16.92

Discharge - 11 hours.	Charge - 8 hours.
Average K. W. - .42	Average K. W. - .962
K. W. hour output - 4.51	K. W. hour input - 7.7
Average output - 5.8 K. W. hours.	Average input - 10.51 K. W. hours.

Efficiency - 55.0 %

Battery Efficiencies and Average

Chair Car Number 501 - -	46.5 %
Sleeper Pantheon - - -	45.0 %
Sleeper Apollo - - - -	50.3 %
Chair Car Number 4151 - -	55.0 %
Average Efficiency - -	49.2 %

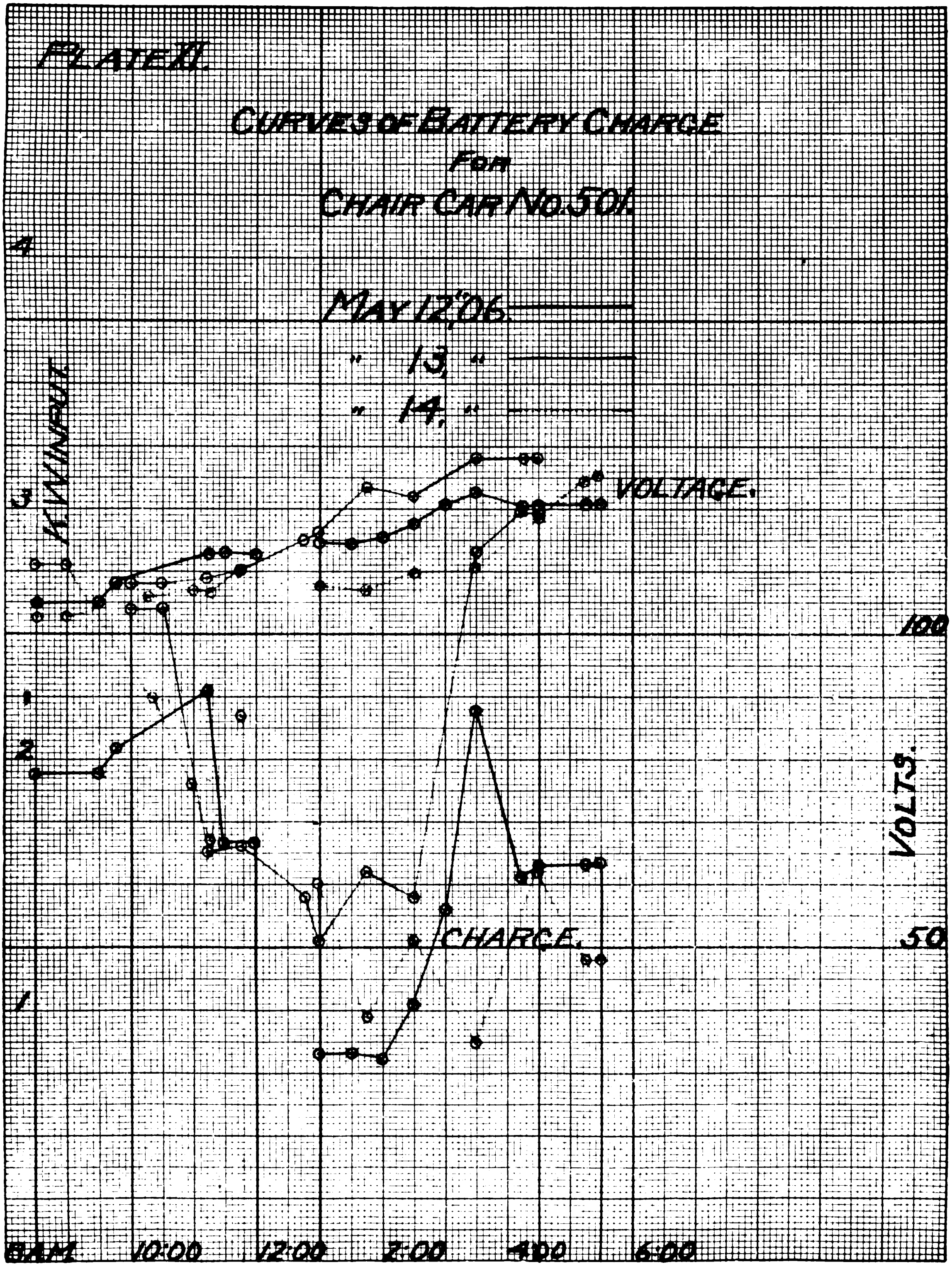


PLATE XI.

CURVES OF BATTERY CHARGE
FOR
CHAIR CAR NO. 501.

PLATE XII.

CURVES OF BATTERY CHARGE
FOR
SLEEPER PANTHEON.

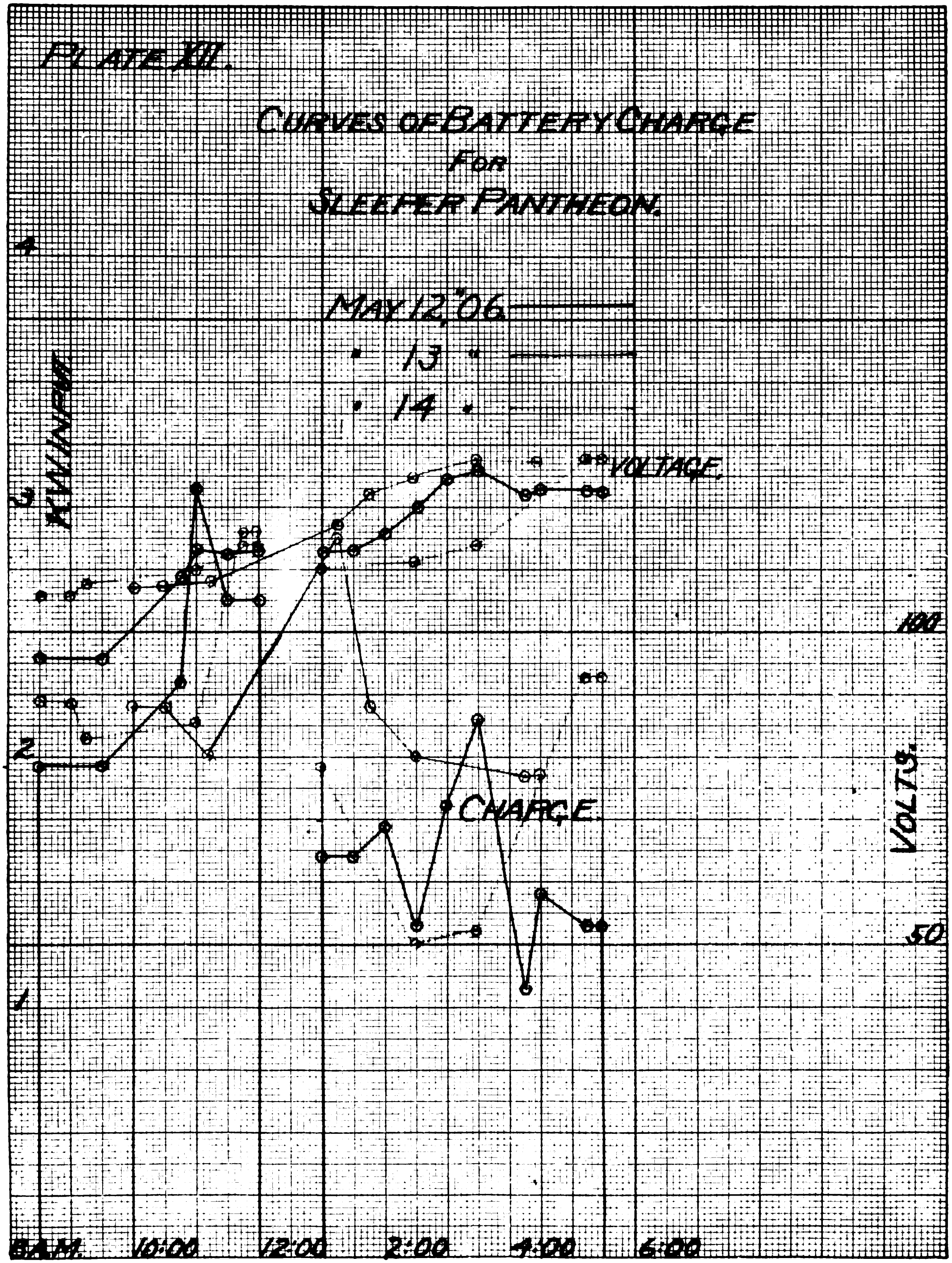
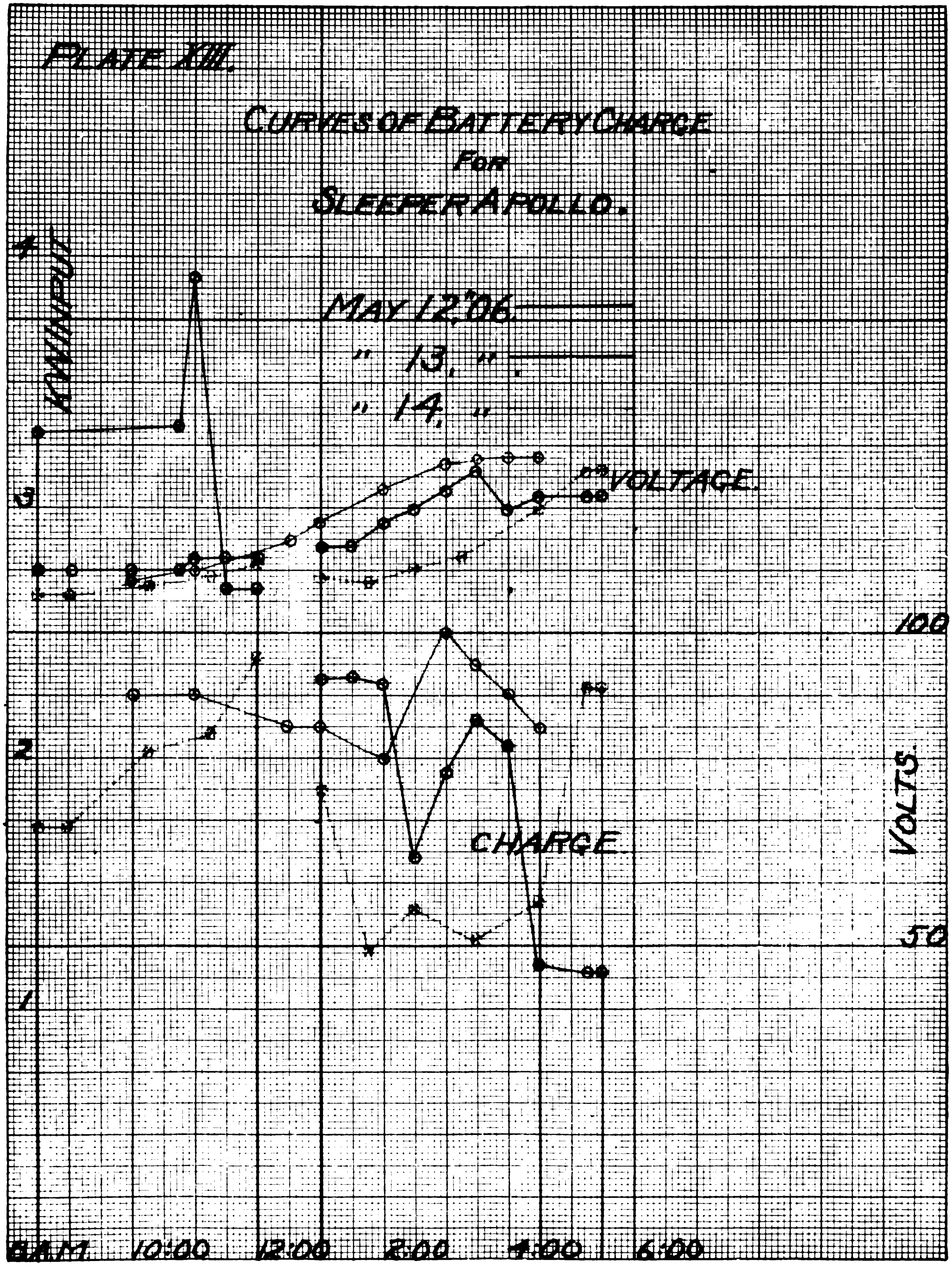


PLATE XIII.

CURVES OF BATTERY CHARGE
FOR
SLEEPER APOLLO.



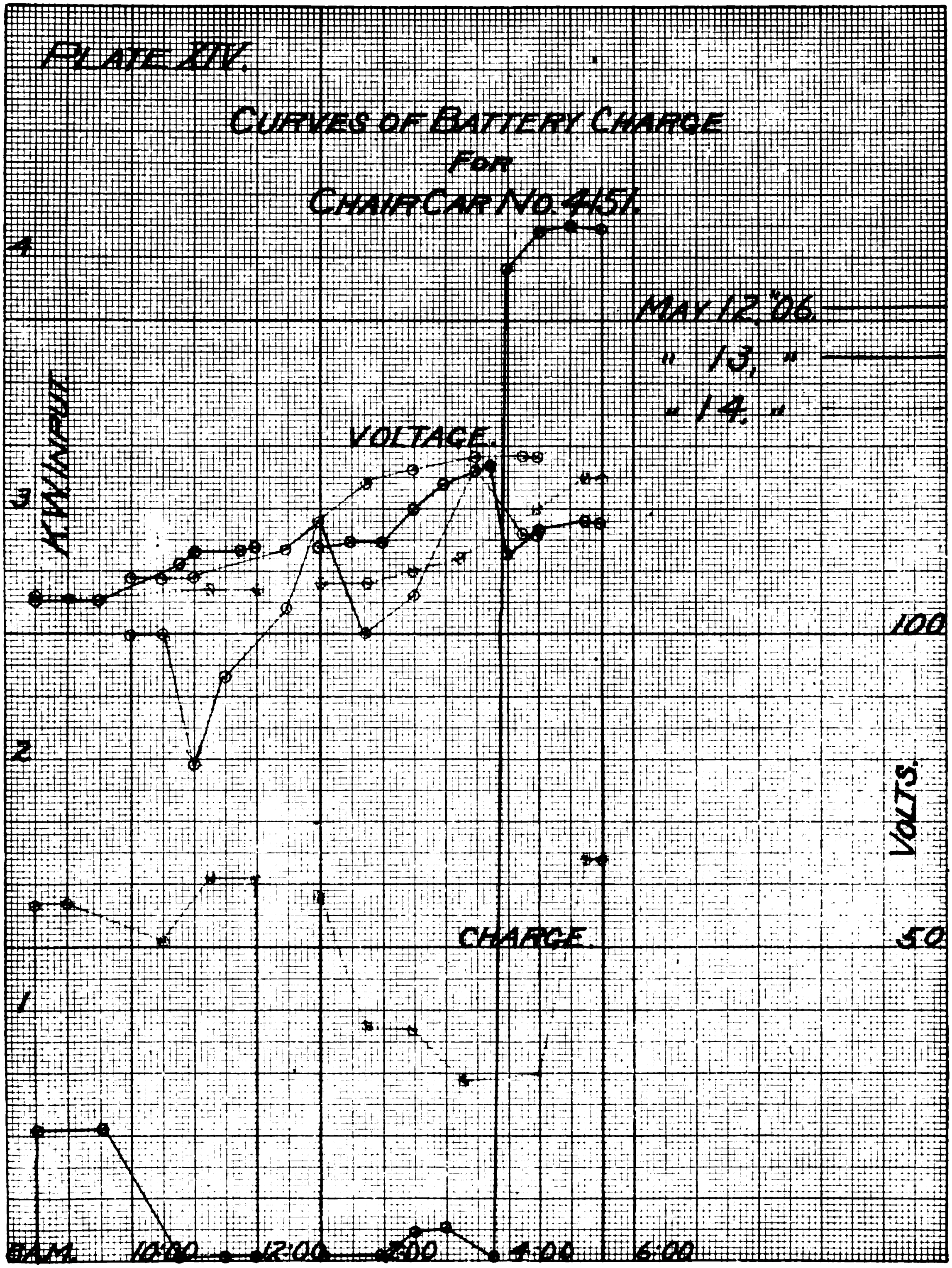


PLATE XIV.

CURVES OF BATTERY CHARGE FOR CHAIR CAR NO. 4151.

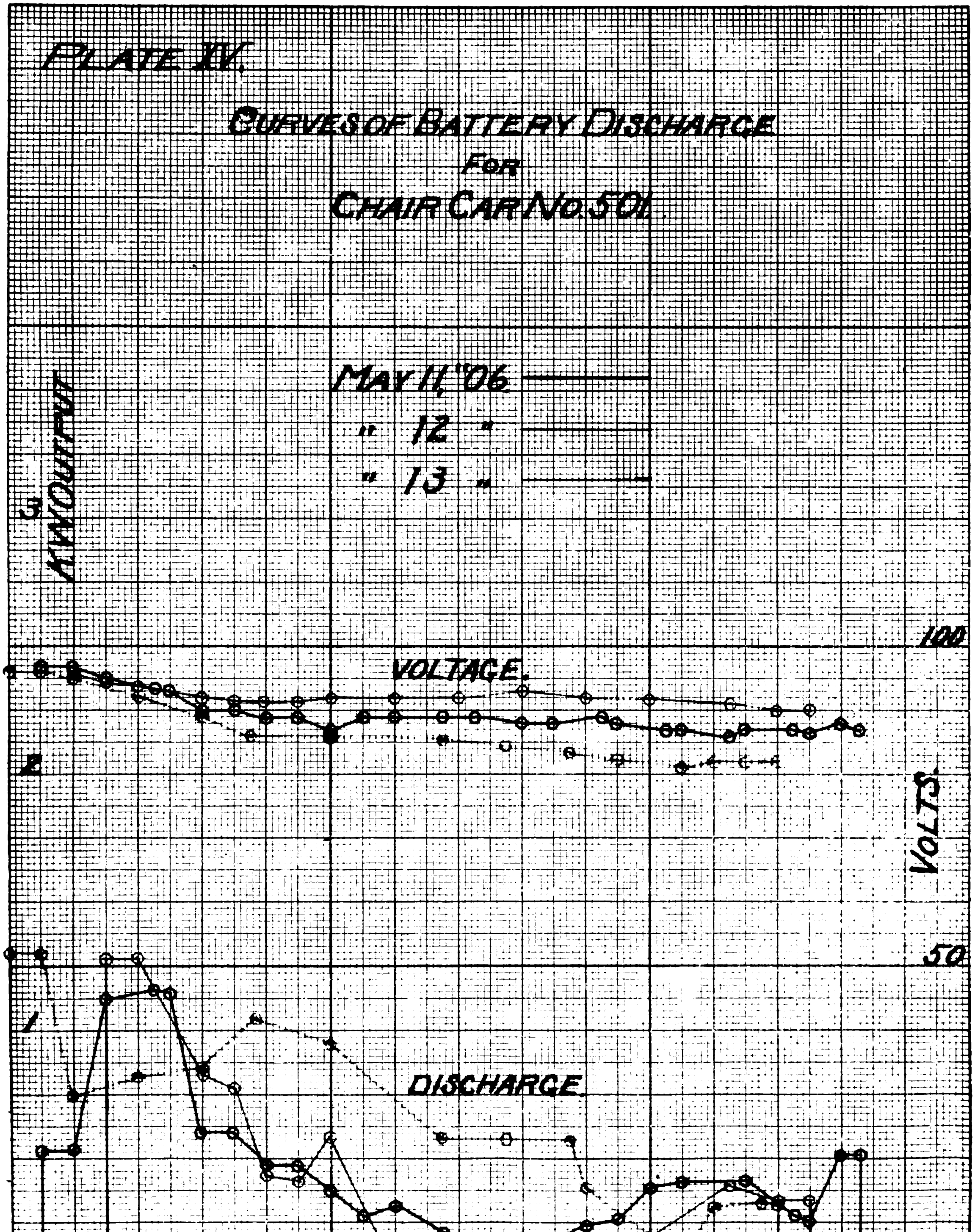
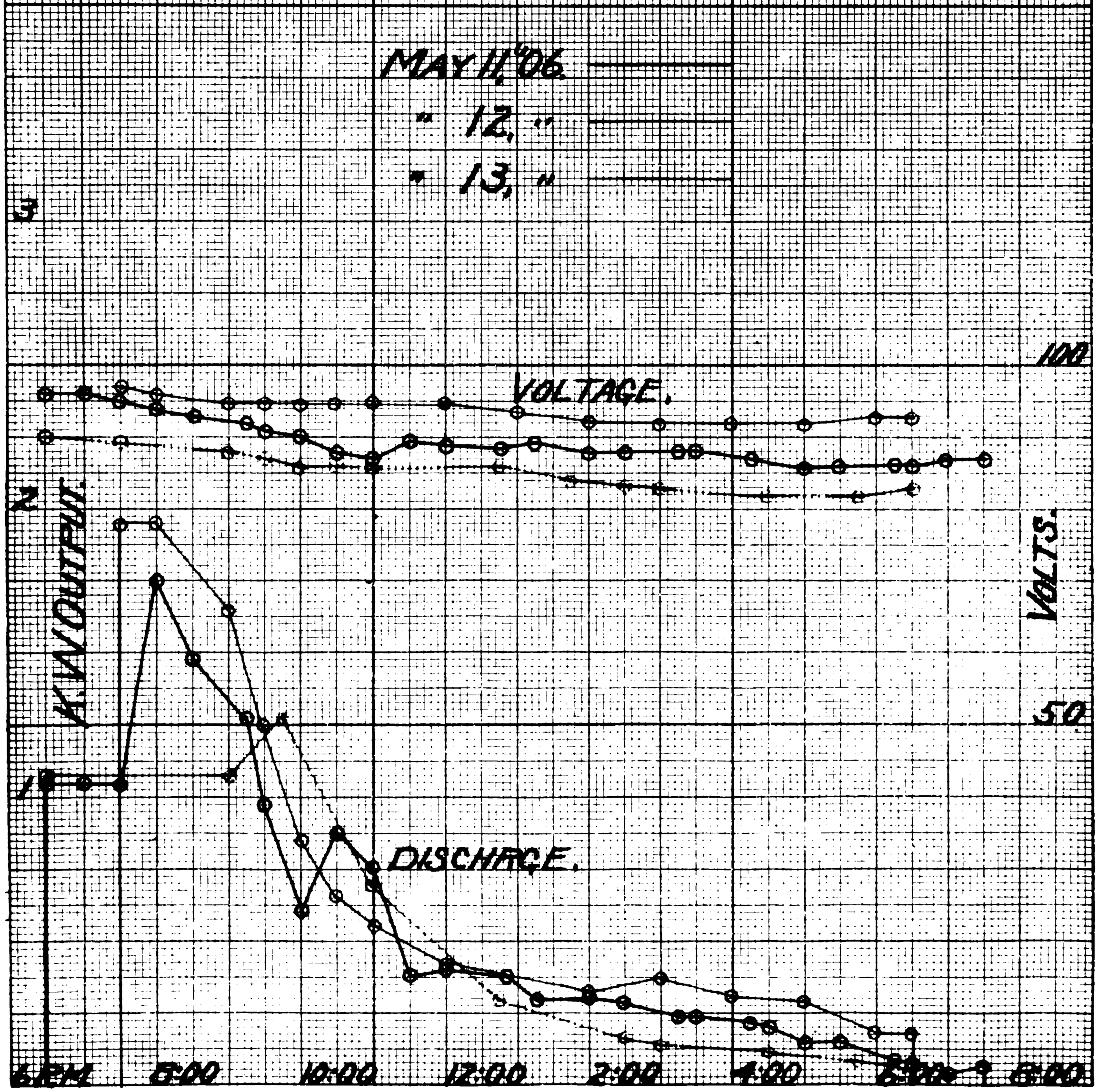


PLATE XIV.

CURVES OF BATTERY DISCHARGE FOR CHAIR CAR NO 501.

PLATE XVII.

CURVES OF BATTERY DISCHARGE FOR SLEEPER PANTHEON.



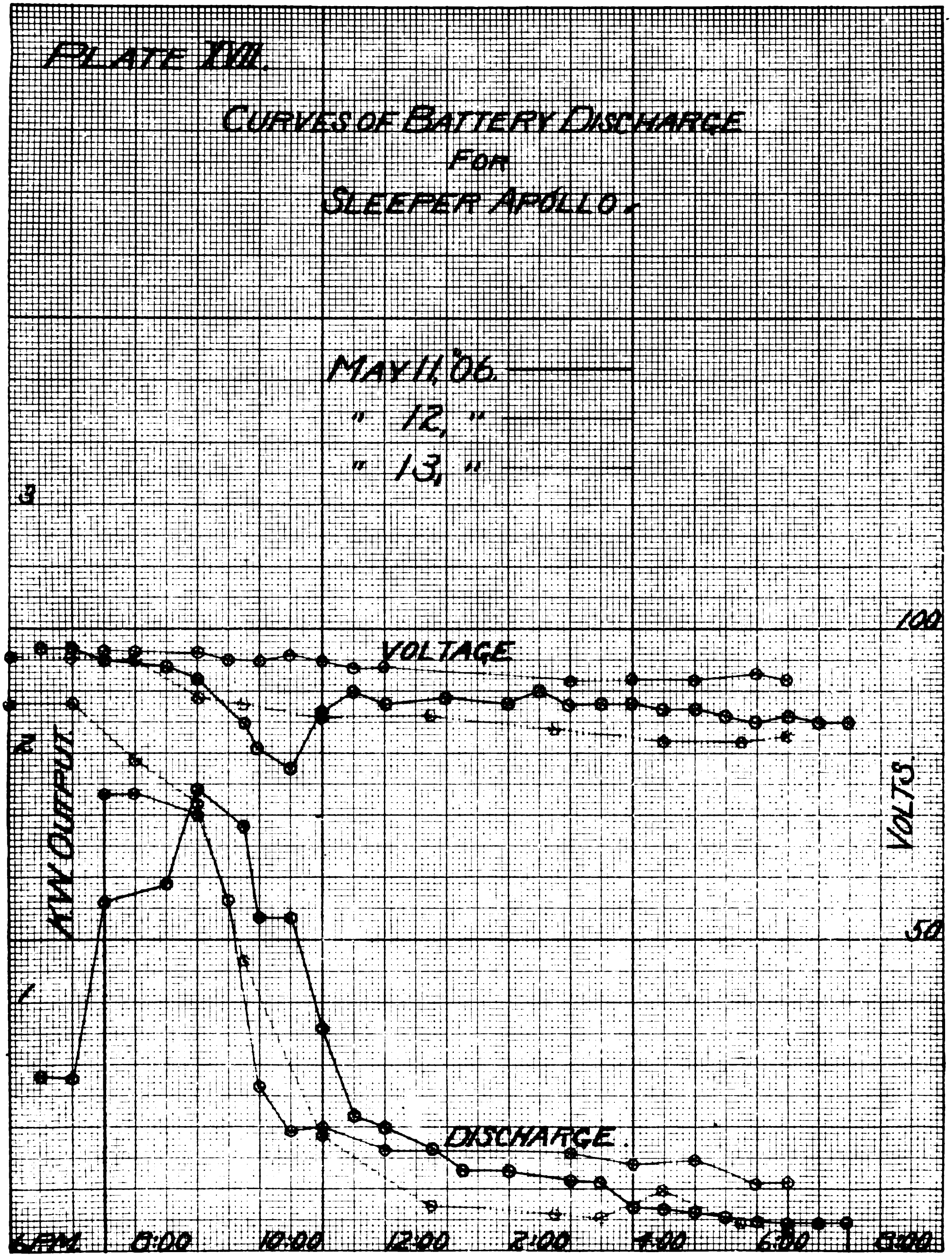


PLATE XVII.

CURVES OF BATTERY DISCHARGE
FOR
SLEEPER APOLLO.

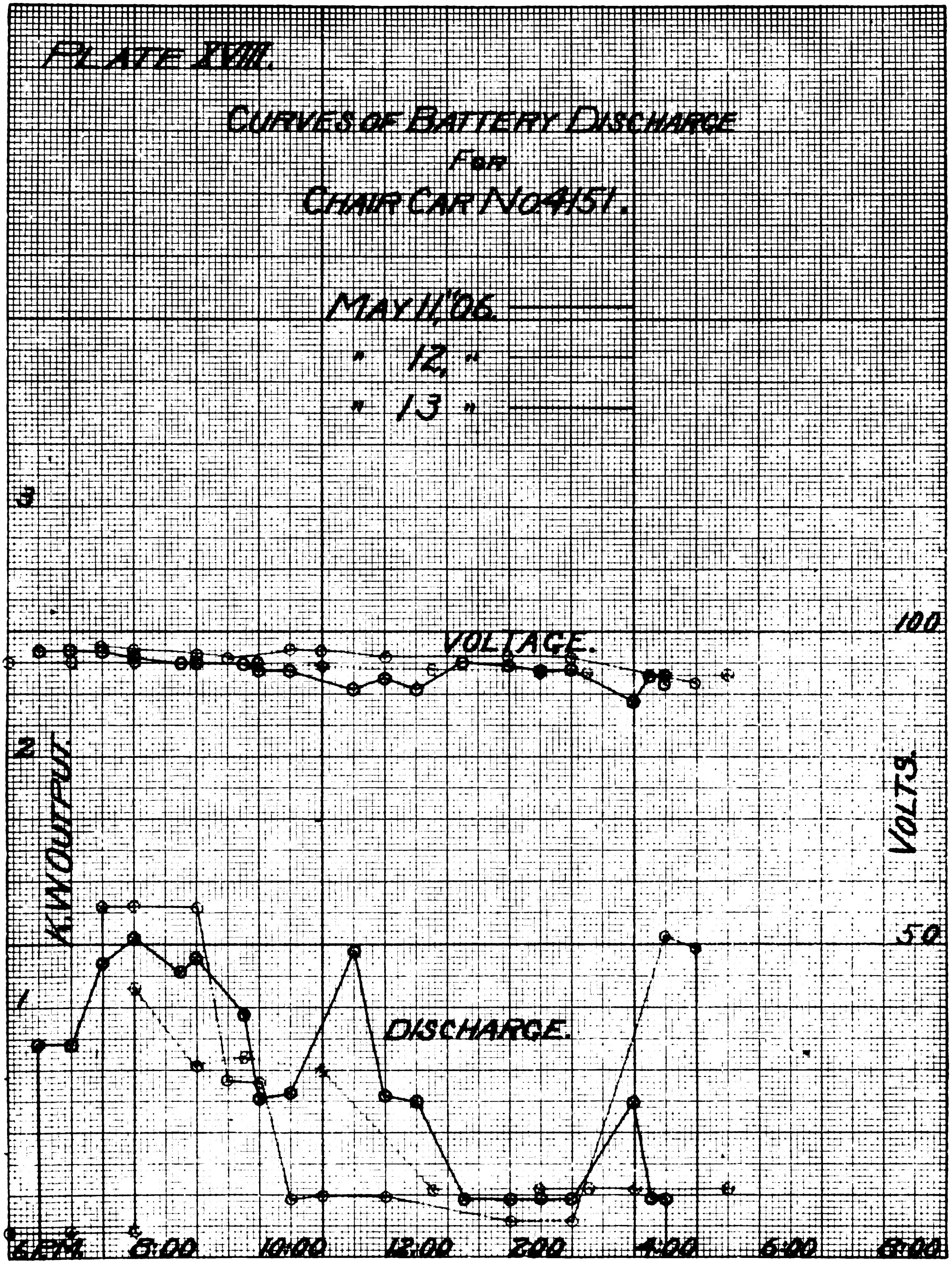


PLATE XVIII.

CURVES OF BATTERY DISCHARGE FOR CHAIR CAR NO 4151.

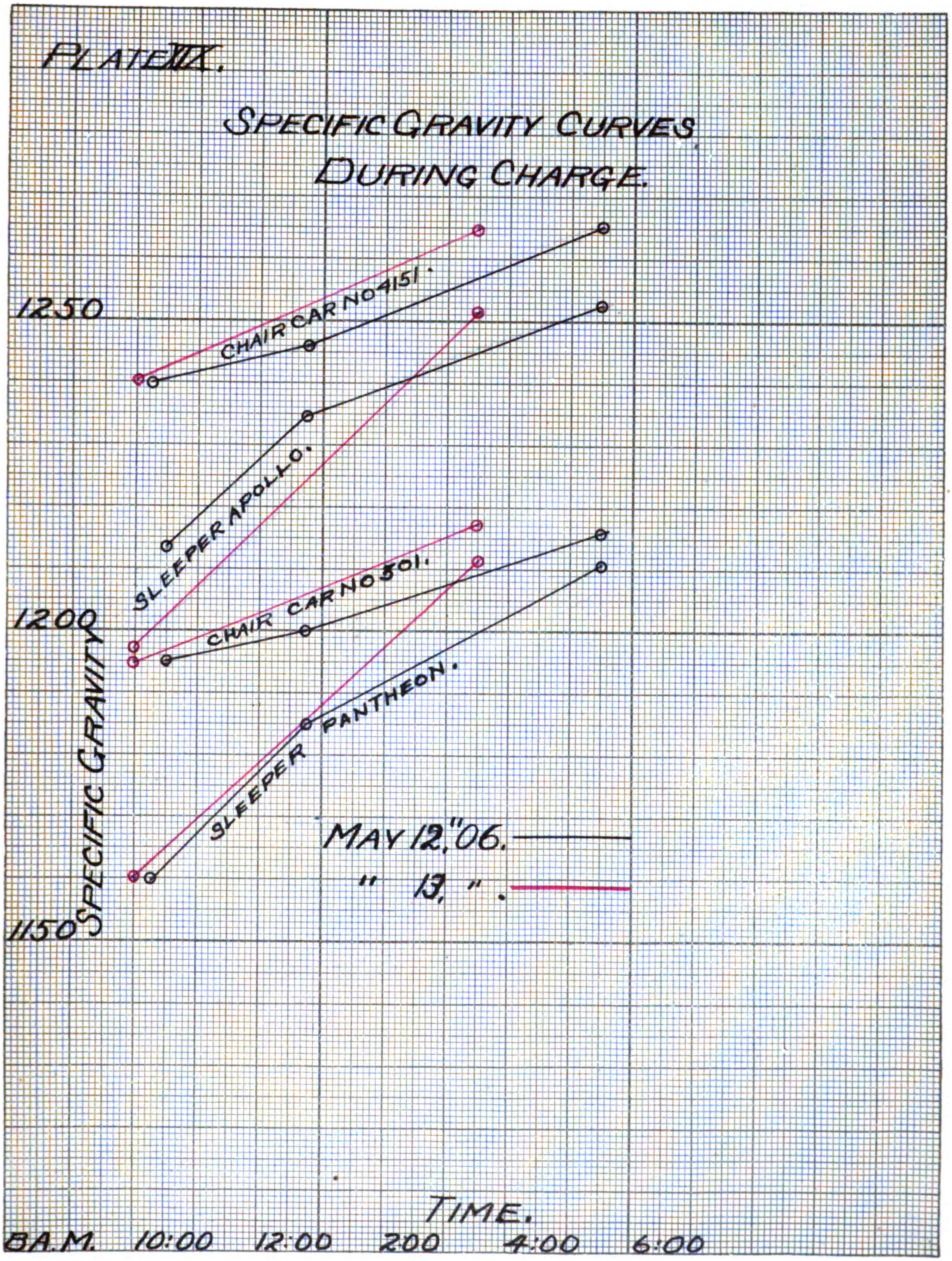
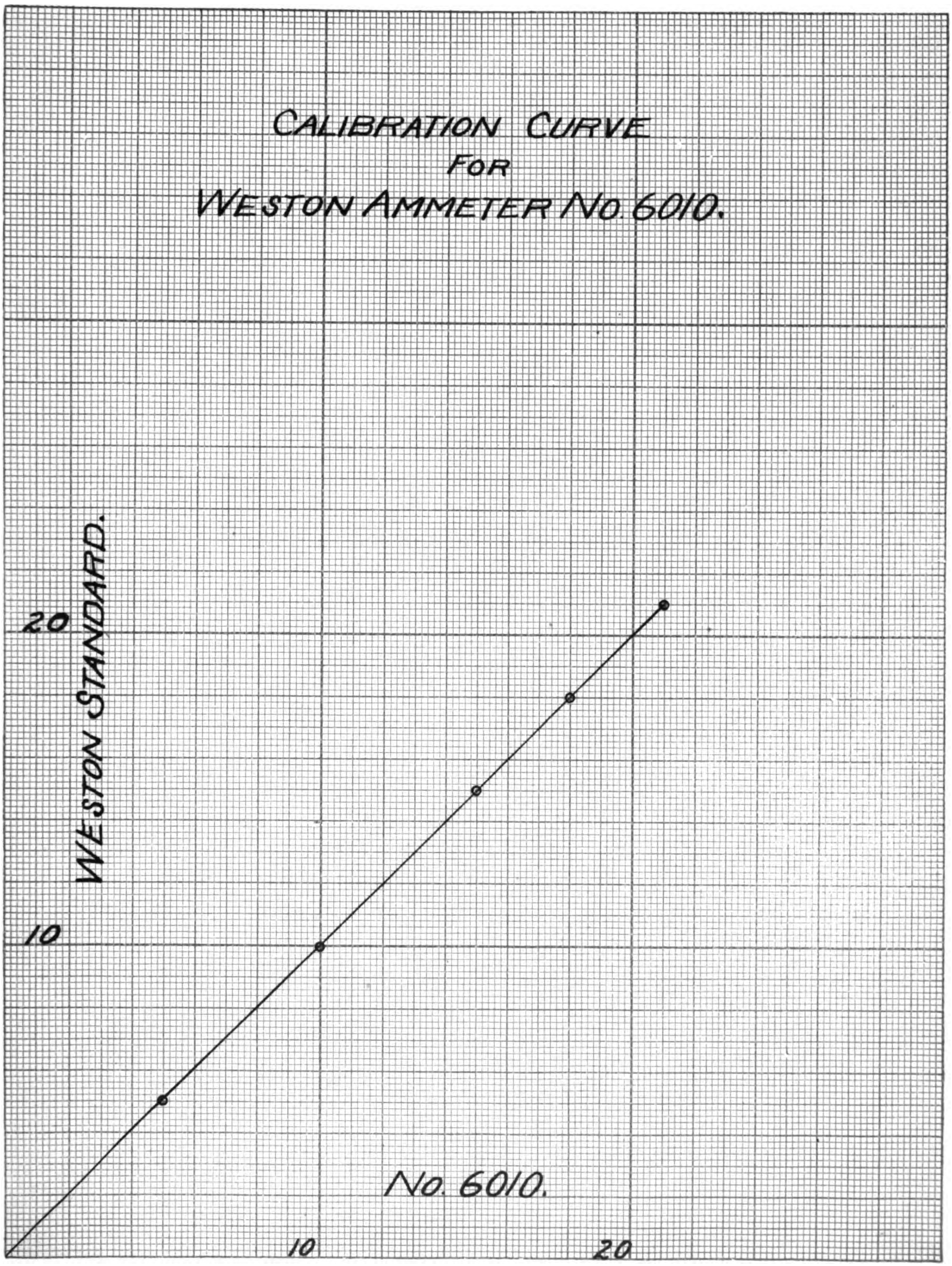
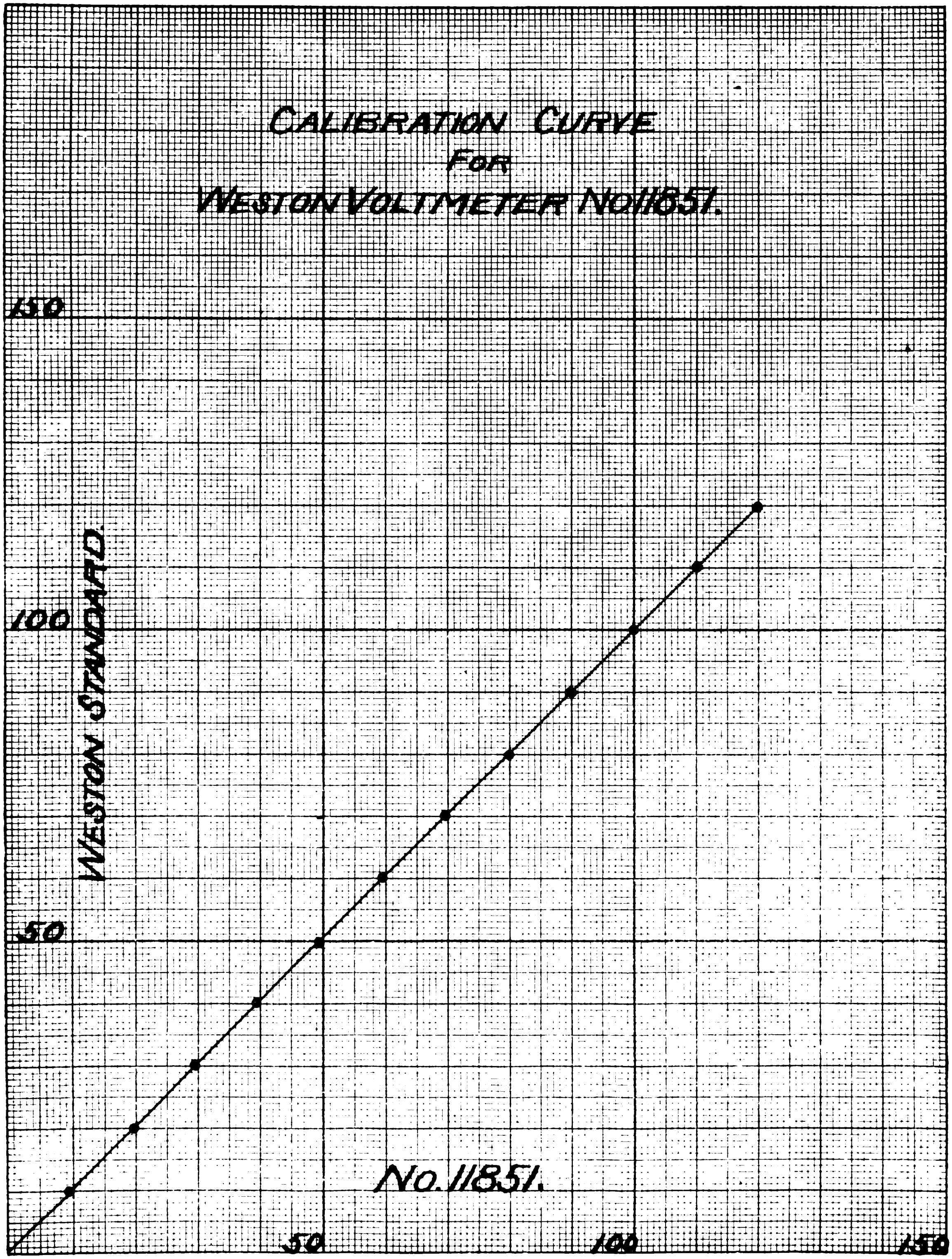


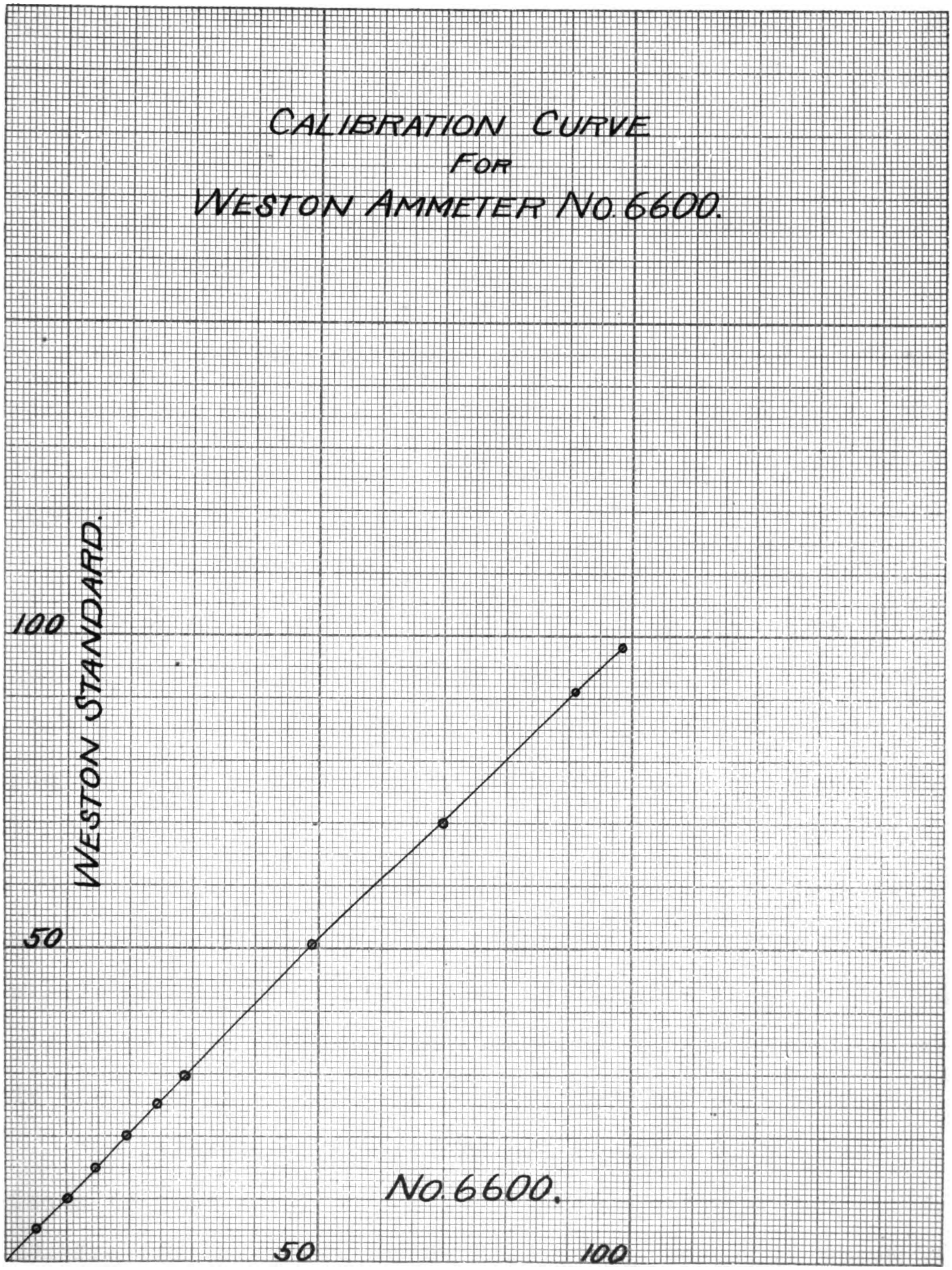
PLATE IIX.

SPECIFIC GRAVITY CURVES DURING CHARGE.



CALIBRATION CURVE FOR WESTON AMMETER No. 6010.


CALIBRATION CURVE
FOR
WESTON VOLTMETER No11851.
150
100
50
WESTON STANDARD.
No.11851.
50
100
150


CALIBRATION CURVE
FOR
WESTON AMMETER NO. 6600.
WESTON STANDARD.
100
50
NO. 6600.
50
100

TEST OF FARNSWORTH CONSOLIDATED AXLE EQUIPMENT

The axle driven equipment of the Consolidated Farnsworth type consists essentially of a generator, pole charger, battery, regulator, automatic switch, and wiring and switches within the car.

The GENERATOR, Plate XX, is a bipolar, simple, shunt wound type and is provided with self oiling bearings. It is encased in a dust proof wrought iron casing, which is provided with suitable covers and hand holes for repairs and inspection. It is suspended by irons bolted to the outer face of the forward truck sill, (see Plate XXI) and is pivoted on a rocker roller, a heavy adjustable spring (A) maintaining proper belt tension. The generator is equipped with a pulley ten and one-fourth inches in diameter which is belted to a large axle pulley. These pulleys are perforated to permit the removal of sand and cinders from the belt surface.

The generator FIELD PIECES are supplied with a few sheets of hard steel to insure proper polarity of the fields.

The POLE CHARGER is that part of the apparatus which

maintains proper polarity in the circuit irrespective of the direction of car motion and consists of a worm fitted on the armature shaft (Plate XX, at a) this engaging with a worm wheel on which is mounted a cam of peculiar construction, such that if the direction of car motion be forward the cam follower will run continuously in the cam slot, but if the direction of car motion be reversed, thus also reversing the direction of rotation of the cam, the follower will be forced through a diagonal slot into another groove, where it will remain as long as the direction of motion is the same. As this cam follower is forced into this slot on reversal of car motion it causes a switch shown at (d) to be thrown in the reverse direction thus maintaining proper polarity in the external circuit irrespective of the direction of car motion.

This is obviously very essential to the operation of the equipment for if the generator were thrown on the line with wrong polarity it would cause an immediate short circuit of both generator and battery through each other.

The BATTERY is composed of 16 cells of 240 ampere hour capacity of the type 13 E of the Electric Storage Battery Co. which are located under the car. The battery is connected in parallel with the generator and line, serving to act as auxiliary in maintaining the lights lit while the generator

is inoperative.

The REGULATOR is the important part of this equipment from a technical point of view. It is shown complete on Plate XXII and wiring detail connections on Plate XXIII. The principle on which the regulator is based is that of voltage control by variable resistance. It consists essentially of a large controlling solenoid (A), (see Plate XXII) an automatic switch (C) operated by the electromagnets (B) and (D), an operating motor (E), a field resistance, the contact points of which are shown at (H), and a lamp resistance at (M).

As the train speed reaches such a value that the generator voltage is equal to that of the battery the magnetism created in the two generator shunt coils (D) which are mounted on a movable arm will be such as to draw themselves up to the magnet (B), thus closing the switch (C) connecting the generator in parallel with the battery and lights.

As the generator speed increases further the voltage tends to rise above that of the batteries and the generator assumes its load. The generator current flowing through the large solenoid (A) will actuate an iron plunger (J) in direct proportion to current flowing, this magnetic pull being counterbalanced by an adjustable spring (K) the adjustment of which determines the value of the normal generator current.

The motion of this magnetically controlled plunger is transferred by the lever arm (O) to the control of two little ratchet dogs (P) which are being actuated back and forth continually by an eccentric on the motor driven worm wheel (F). These little ratchet dogs engage with two ratchet wheels one of which is right handed and the other of which is left handed as per Plate XXIV, These wheels being rigidly mounted on the adjustable field rheostat arm (R). When regulation is necessary, one of the ratchet dogs (P) will be allowed to engage with its corresponding ratchet wheel (G) and will cause it to be rotated, moving the field rheostat arm (R) to such a point as to produce the desired regulation. It is obvious that only one of these motor driven dogs may be allowed to engage with its corresponding wheel at one time. A lamp resistance (M) is inserted in the lamp circuit when the generator becoms operative, to compensate for the difference between battery charging voltage and discharge voltage, thus maintaining constant voltage on the lamps. This is effected by the rheostat arm resistance contact points at (M), being operated by a cam and follower mounted on the ratchet wheel (G) of such construction that it causes the resistance to be all inserted at the first quarter turn of the ratchet wheel.

The automatic switch (B, C, D) operates as follows:-

when the magnetism in the generator shunt (D, D) becomes of sufficient intensity, they will be drawn up to (B, B) closing the generator switch (C). The coils (B, B) are wound with heavy wire and all the generator current passes through them so that on closing the generator switch (C) the generator current flowing through the coils (B, B) will intensify the magnetic pull of the shunt coils (D, D) and thus insure good contact. The series coils (B,B) have also a very important function in operating the automatic switch at the proper time, as the generator voltage falls below that of the battery, a current will flow in the reverse direction through the series coils (B, B) creating a magnetic flux in opposition to that of the shunt coils (D, D) and will actually blow the switch open. If the shunt coil only, had been used to operate the automatic switch, it is obvious that the battery pressure would tend to hold it closed, even far below the critical speed since the battery, generator, and shunt coils are all in parallel relation when the switch is closed, and a destructive short-circuit would occur, or if the automatic switch did open it would do so under heavy arcing of this battery discharge current.

METHOD OF TESTING

The problem of testing such an apparatus in actual operation on a railway train is a peculiarly difficult one. In the first place everything in the system is in continual fluctuation,- the speed of a train is well known to be extremely variable, and it may be said that everything in the system fluctuates with train speed, though it must be said that the limits of fluctuation of generator pressure and current for change in speed are very small but still they are by no means constant. In addition to this the generator is alternately thrown off and on, at every stop and start, the lights being fed at one minute from the generator and at another from the battery, so that the equipment presents a rather chaotic appearance to one endeavoring to obtain a comprehensive set of results.

It was decided to take two different kinds of data, one of which might be called DETAIL DATA - which considers the detail operation of the equipment and includes that data which would, when plotted in curves, show the relation between speed, generator pressure, light pressure, battery

pressure and pressure impressed across the field and the generator current, light current, battery current, and field current; readings being taken in most cases from stop at one station to a stop at another, the train speed having in the meantime gone far above the critical speed. Sets of such data were taken at various times throughout the day and night as was deemed necessary. It was found that the night conditions of generator operation were practically constant so long as all lights were kept burning, and therefore one good set of detail data each night was thought sufficient to show this operation. In the daytime, however, conditions were different. The batteries in the morning were partially discharged and as the lights were thrown off, the generator began charging the batteries at slightly above normal voltage. As the batteries became more fully charged their pressure would rise and the generator pressure would rise proportionally, so it was necessary to take detailed data at more frequent intervals during the daytime.

In order to take almost simultaneous readings of generator voltage, lamp voltage, battery voltage, generator current, lamp current, battery current and field current, for which but two ammeters and one voltmeter were available, a switchboard was constructed as shown in Plate XXIII, which made it possible to take the whole set of readings within

ten seconds time. This switchboard contained all the numerous switches and instruments used in making the tests and was placed in the closet which contained the regulator. In wiring to the regulator, heavy insulated copper cables were used corresponding to number 4, B and S gauge so that the loss in test connections would be a minimum. It may be easily seen on Plate XXIII what connections were made from our switchboard to the regulator circuits, so as not to interfere with the operation of the equipment.

The detail of the switchboard is self-evident and will not be further discussed here.

The other set of data might be called INTEGRATED DATA or data of totals. It is evident that a knowledge of the total generator output, total consumption, total battery charge, total battery discharge and total time of generator operation one of utmost importance to a consideration of the performance of the equipment. In order to determine the generator output and line consumption, wattmeters of common intergrating type were placed in each of the circuits and readings of dials taken at the beginning of the trip and twice each day - once when the lights were turned off in the morning and again when they were turned on in the evening. The separation of the battery charge and discharge presented a more complex problem as the current flows into the battery

one minute and out the next. To separate these two values of charge and discharge, a polarized relay was constructed as per Plate XXV to operate two wattmeters one of which recorded battery charge and the other battery discharge. This polarized relay consists essentially of a heavy yoke of soft iron wound with about forty turns of number four insulated copper wire through which the total battery current passes thus creating one polarity on charge and the reverse polarity on discharge. Suspended between the pole pieces of this yoke is one end of an electromagnet of constant polarity. It consists of a small strip of soft iron wound with four hundred turns of number twenty insulated copper wire. This coil is placed in series with two lamps directly across the battery so that a constant magnetic flux is obtained. Fitted on either side of this swinging bar of iron is an insulated brass button. When the battery current flows in - say a charging direction, the reaction between the magnetism of the yoke and that of the swinging magnet will draw the latter over till the brass button makes contact between two adjustable points, thus completing the circuit through the voltage coil of the wattmeter registering battery charge. The current coils of both wattmeters are placed in series with the heavy coil of the relay so that all battery current must pass through all three coils. On reversal of the

battery current the polarity of the heavy yoke will be reversed and the swinging magnet will be drawn over to the other yoke pole where the brass button on the other side of the swinging bar will make contact between the two contact points thus completing the circuit through the voltage coil of the discharge wattmeter causing it to record, the other wattmeter being inoperative.

There are two pilot lights in the switchboard equipment which show when the corresponding wattmeter is operative, thus indicating whether or not the relay is working properly.

The other variable factor which it was necessary to determine was the total time of generator operation. A clock was fitted up on the principle of a stop watch as per Plate XXVI. This clock was mounted on our switchboard, and an electromagnet was placed in the generator circuit so that during generator operation, the lever arm shown in Plate XXVI was drawn down and held firmly. When thus held the lever arm pressed against the balance wheel of the clock and prevented its moving. The instant current stops flowing in the coils of the electromagnet due to the generator becoming inoperative, the lever arm is raised by means of a spring, thus permitting the running of the clock. The clock thus records the total time that the generator is not supplying current to the line.

The SPEED of the train was determined by counting rail clicks, which in case of a thirty foot rail, the number of rail clicks in twenty and one-half seconds gives directly the speed of the train in miles per hour. In case of a thirty-three foot rail the clicks were counted for twenty-two and one-half seconds. This was found to be a very simple and sufficiently accurate method of speed determination.

On arriving at Chicago a STRAY POWER test of the generator was made by rated motor method. The belt was removed and the generator driven at various speeds and no load on armature by means of a small motor, the losses of which had been previously measured. The input of the motor was then measured while driving the generator light at various speeds and various excitations from which the power necessary to supply these generator losses was determined. Knowing the stray power losses and armature resistance of the generator the power absorbed from the axle by the generator while delivering any load to the lighting equipment can readily be computed from which efficiency curves follow.

IMPORTANT RESULTS OF TEST

Chicago to Kansas City

Total time of trip	14 hours, 10 minutes
Total time generator operative	11 hours, 35 minutes
Total time generator not operative	2 hours, 35 minutes
Total time of stops	1 hour, 22 minutes
Total time generator running dead	1 hour, 13 minutes
Total time lights on batteries	2 hours, 35 minutes
Total generator output	19.60 K. W. hours
Total lamp consumption	8.38 K. W. hours
Total battery charge	7.90 K. W. hours
Total battery discharge	1.86 K. W. hours

Kansas City to Chicago

Total time of trip	13 hours, 42 minutes
Total time generator operative	10 hours, 55 minutes
Total time generator not operative	2 hours, 47 minutes
Total time of stops	1 hour, 24 minutes
Total time generator running dead	1 hour, 23 minutes
Total time lights on batteries	2 hours, 47 minutes

Total generator output - - - - 19.20 K. W. hours

Total lamp consumption - - - - 7.28 K. W. hours

Total battery charge - - - - 7.03 K. W. hours

Total battery discharge - - - - 1.87 K. W. hours

Average generator efficiency - - - - - 80.8 %

Total efficiency of equipment - - - - - 40.4 %

Readings were corrected for loss in test connections.

DISCUSSION OF RESULTS

The most striking of the results obtained and that which is of most critical importance to the life of the equipment is that the batteries are tremendously overcharged on both outgoing and return trips as seen by a comparison of the values of battery charge and discharge on page 50. The cause of this is primarily due to the fact that the regulator was set too high but as in the case of the Newbold equipment, is really inherent in the fundamental principles underlying the operation of the regulator itself. Instead of being a regulator for constant voltage, it is a constant regulator. This is found to be inherent in the control of the large solenoid. It is noted from the description on page 41 that the iron plunger (J) which controls the operation of the full rheostat is held in equilibrium between the magnetic pull of the solenoid winding and the tension in the spring (K). Now the magnetic pull by the coil (A) is directly proportional to the current flowing through that coil and is no function of the generator voltage, so that

the regulation will be such as will maintain constant current output of the generator irrespective of its voltage. This is a very great disadvantage from battery standpoint in that after the batteries have become fully charged they still continue to be overcharged at the normal rate so long as the generator is operative.

Attention should be called to the fact that the total efficiency of the outfit is 40.4 %. This is due largely to the fact that the batteries are greatly overcharged thus wasting a large amount of power and also is shown by the exceedingly high generator output, being considerably higher than the sum of the line consumption and the battery charge minus the battery discharge. This indicates a very high line loss and is substantiated by reference to the large curve sheet which shows an average line loss of about 13 %.

The values given under wattmeter readings on page 50 have been duly corrected as per page 63 so that the readings are true values. It should be noted that the voltage connections of the wattmeters were taken over special leads from the generator, line and battery, so that the readings do not include any line drop, except that of the generator which of course includes all.

In discussion of the detail curves, Plate XXVII, of operation there are many important features to be noted,

which are typical in the operation of this equipment. It should be first noted that these curves are in four different sets, one under full load condition of lighting, another with but half the lights on, a third with about one fourth of the lights burning, and the fourth set of curves indicating detail operation while charging batteries with no lights on. The uppermost curve shows that the generator current remained practically constant at all times, whether all lights were on or one-fourth lights on or charging batteries. This substantiates the statement that the regulator is for constant current irrespective of the generator voltage.

Another point of particular interest in the curves is the variation in line voltage as the line current decreases and the batteries become charged. It is also noted that the line voltage varies directly and is almost equal to the battery charging voltage thus indicating the absolute impossibility of lamp regulator irrespective of battery charging voltage by this method of inserting lamp resistance.

Another point of technical interest is shown by the two lower curves in the inverse variations of field current and train speed, an increase in train speed being always accompanied by a decrease in field current and vice versa.

CONCLUSION

In conclusion a consideration of the proper adjustment of the regulator to obtain proper performance of the equipment would be of special interest.

CALCULATION OF REGULATOR ADJUSTMENT:- From the wattmeter data page 50 it is seen that for a round trip the batteries receive an overcharge of 11.2 K. W. hours. The total time of generator operation is twenty-two and one-half hours. Assuming the battery voltage an overcharge to be 40 volts, then generator output is set too high by

$$\frac{11200}{22.5 \times 40} = 12.45 \text{ amperes}$$

This does not consider the battery efficiency which would make a somewhat higher setting necessary. Inculding this in the calculation, battery output is 3.72 K. W. hours. at 70 % battery efficiency would require 5.3 K. W. hours or an increase in the setting of the regulator of

$$\frac{(5.3 - 3.72)\ 1000}{22.5 \times 40} = 1.96 \text{ amperes}$$

therefore the regulator is set too high by the difference of these values computed or 12.45 - 1.96 = 10.5 amperes. There fore the regulator should be set at 31.5 amperes instead of 42 as it is at present.

PLATE XX.

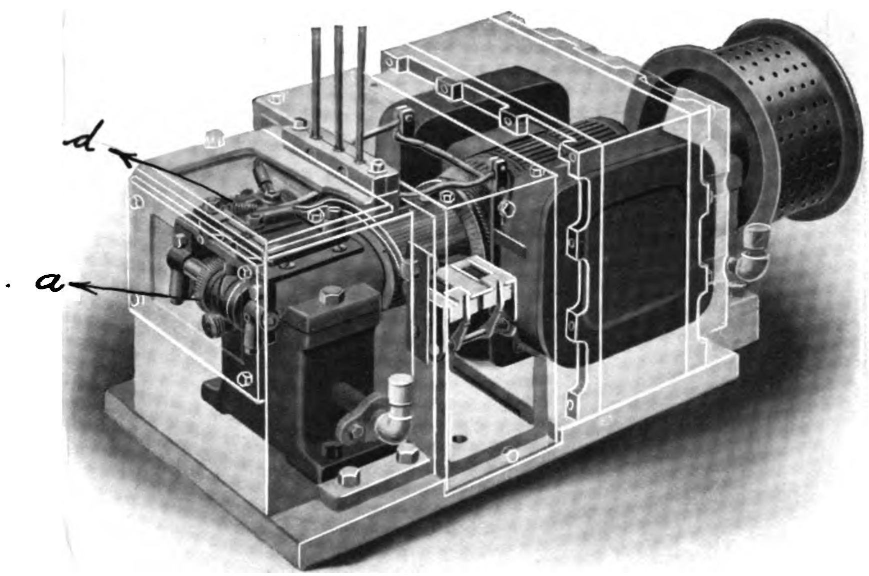


PLATE XXI.

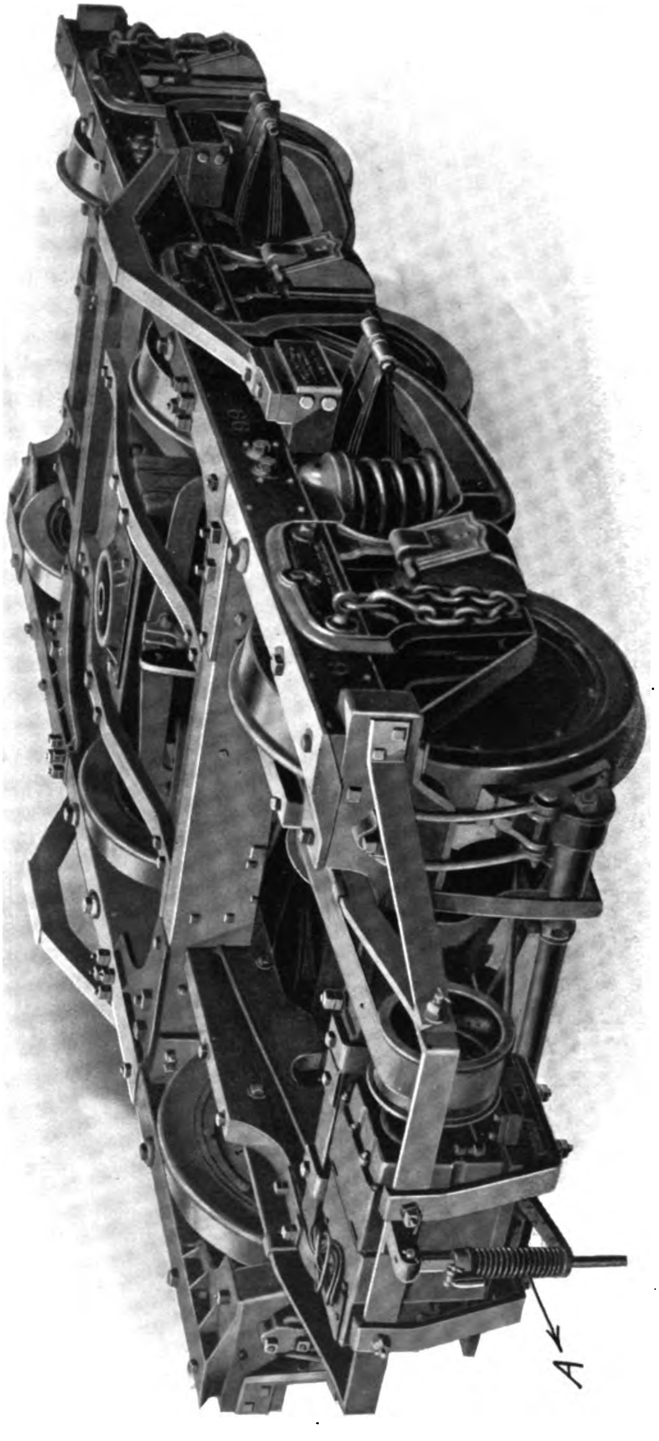
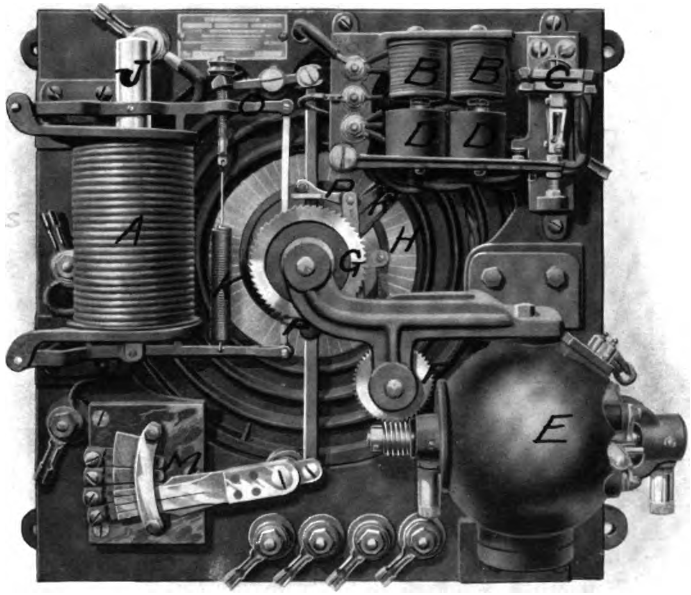


PLATE XXII.



THE REGULATOR

PLATE XXIII.

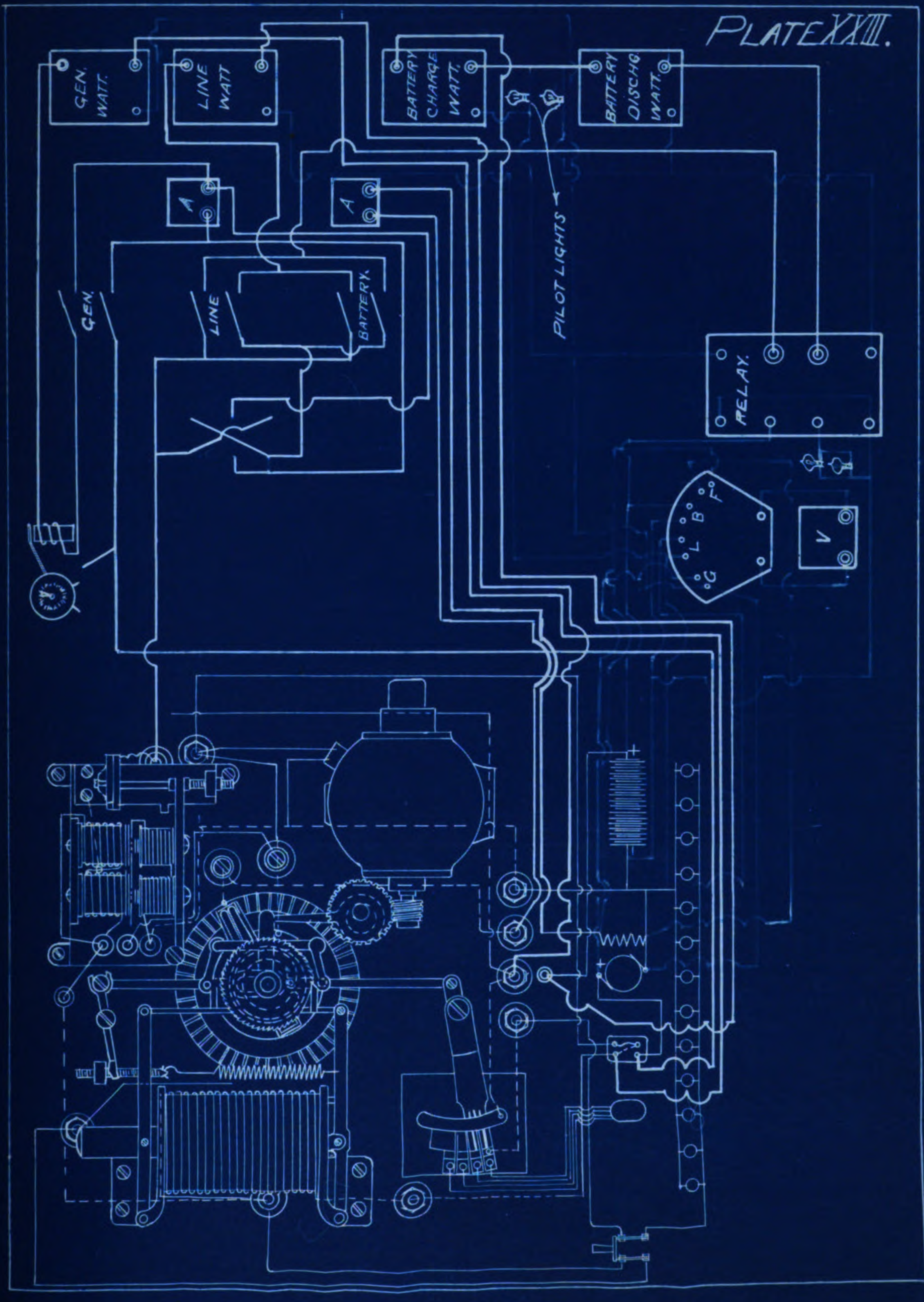

GEN. WATT.
LINE WATT
BATTERY CHARGE WATT.
BATTERY DISCHG WATT.
A
A
GEN.
GEN.
LINE
BATTERY.
BATTERY
PILOT LIGHTS
RELAY.
G
L
B
F
V

PLATE XXIV.

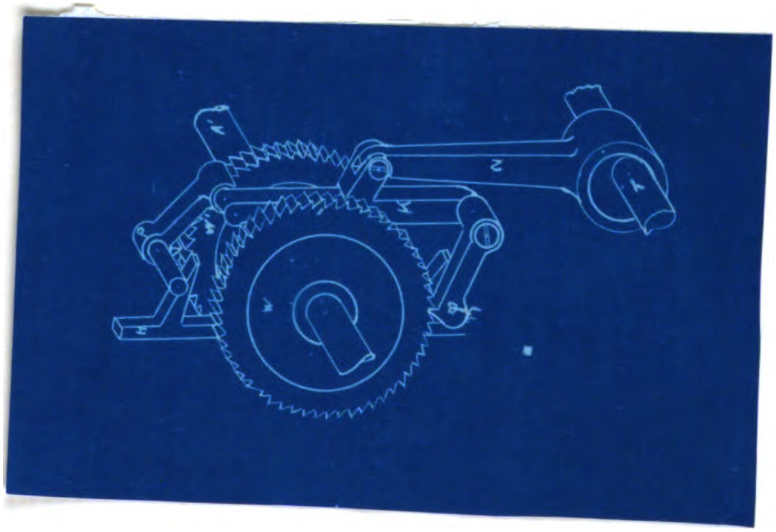


PLATE XXV.

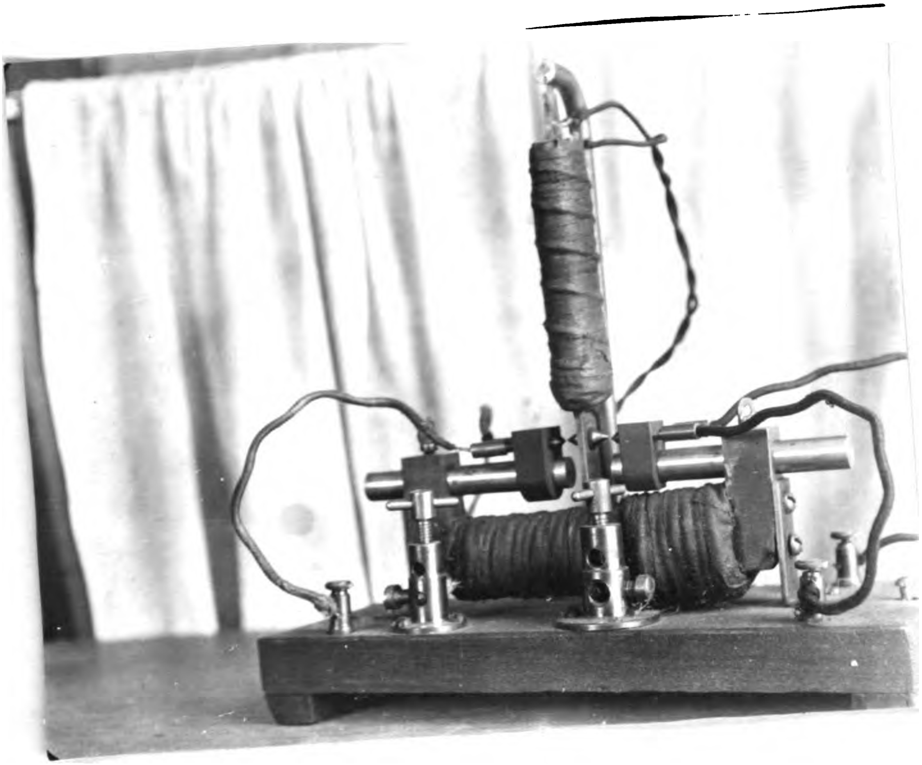
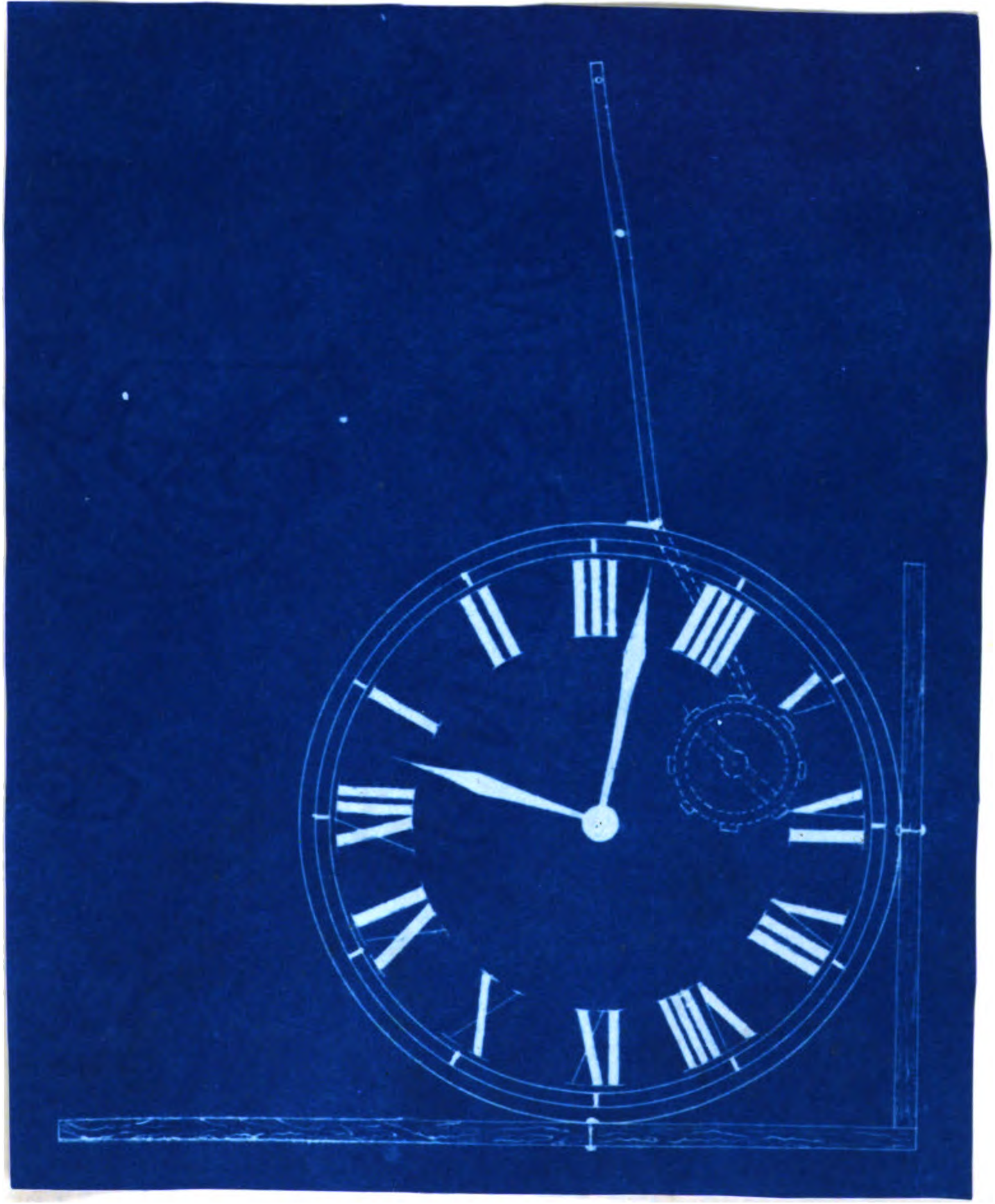


PLATE XXVI.



DATA OF AXLE DRIVE TEST

TESTS ON TRAINS 55 AND 56
RUNNING BETWEEN CHICAGO AND KANSAS CITY
EQUIPMENT ON OBSERVATION CAR DYNAMENE

Data of Trip on Train 55
From chicago to Kansas City, May 9, 1906

	VOLTAGE				CURRENT					
Time P. M.	Generator	Line	Battery	Field	Generator	Line	Battery	Field	Speed Miles per Hour	
9:22	0.0	30.0	31.0	0.0	0.0	28.0	30.0	0.00	0	
9:23	Left Kewaunee									
9:30	38.0	33.0	33.0	13.0	41.0	33.0	5.0	2.60	48	Data of
9:32	38.0	33.0	34.0	13.0	40.0	32.0	6.0	2.40	55	Curve 1
9:35	37.5	33.0	34.0	12.0	42.0	34.0	6.0	2.30	60	
9.39	38.0	33.5	33.5	12.0	41.0	33.0	6.0	2.20	65	Full
9:46	38.0	33.5	33.5	14.0	43.0	34.0	6.0	2.50	57	Load
9:54	38.0	34.0	34.0	14.5	43.0	34.0	6.0	2.50	57	
9.57	38.5	34.0	34.0	13.0	42.0	34.0	6.0	2.20	63	
10:00	– 10:10 Stop at Galesburg									
10:08	0.0	30.0	31.0	0.0	0.0	28.0	30.0	0.00	0	
10:58	– 10:59 Stop at Bushnell									
10:58	0.0	33.4	33.8	0.0	0.0	11.0	13.0	0.00	0	
11:02	– 11:06 Stop on Siding									
11:05	0.0	32.0	32.8	0.0	0.0	15.0	16.5	0.00	0	Data of
11:10	41.0	36.0	35.0	18.0	43.0	16.8	23.0	3.10	44	Curve 2
11:12	41.0	36.0	35.5	18.8	41.0	16.8	21.0	3.20	43	
11.14	41.8	36.2	36.0	17.5	44.0	17.0	24.0	2.90	46	Half
11.16	42.0	36.8	36.0	17.5	41.0	17.0	21.0	2.90	50	Load
11.21	41.0	36.8	36.0	17.4	41.0	17.0	21.0	2.80	48	
11:22	– 11:24 Stop at McComb									

11:22	0.0	33.0	33.2	0.0	0.0	14.7	16.5	0.00	0	
11:35	43.5	37.0	37.0	17.5	40.0	5.0	33.0	2.85	53	
11:36	42.5	37.5	37.0	17.0	45.0	2.0	40.0	2.75	57	
11:40	43.0	38.0	37.5	14.0	43.0	2.0	38.0	2.45	53	
12:07	- 12:08 Stop at Colchester									
12:15	45.0	39.0	38.0	21.0	41.0	6.0	33.0	3.40	55	
12:48	- 1:02 Stop at Quincy									
12:51	0.0	35.0	35.0	0.0	0.0	5.8	7.8	0.00	0	
1:08	- 1:10 Stop at West Quincy									
1:15	45.0	39.0	38.0	20.0	41.0	7.0	30.0	3.80	53	
1:31	- 1:35 Stop at Palmyra Junction									
1:33	0.0	35.0	35.0	0.0	0.0	5.5	7.5	0.00	0	
1:45	46.0	41.0	40.0	25.0	45.0	8.0	33.0	3.80	50	
2:13	47.0	41.0	40.0	27.0	42.0	7.5	31.0	4.00	40	
2:30	47.0	41.0	40.0	27.0	43.0	7.5	32.0	3.80	44	
2:44	- 2:47 Stop at Clarence									
2:45	0.0	35.0	35.0	0.0	0.0	9.0	10.8	0.00	0	
3:59	- 4:06 Stop at Brookfield									
4:00	0.0	35.0	35.0	0.0	0.0	5.0	7.0	0.00	0	
4:30	48.0	42.0	41.0	19.0	44.0	6.5	33.0	3.00	53	
4:46	- 4:48 Stop at Chillicothe									
5:00	47.0	41.0	40.0	23.0	43.0	6.5	33.0	3.70	40	
5:45	47.0	42.0	41.0	21.0	44.0	6.8	34.0	3.20	38	
5:57	- 5:58 Stop at Cameron Junction									
5:55	48.0	42.0	41.0	40.0	9.0	6.0	4.0	5.50	38	
6:00	0.0	36.0	36.0	0.0	0.0	8.0	10.0	0.00	0	
6:05	0.0	34.0	34.0	0.0	0.0	8.0	9.8	0.00	0	
6:15	42.0	36.0	36.0	32.0	41.0	9.5	30.0	3.70	44	
6:35	- 6:37 Stop at Lathrop									
6:40	47.0	41.0	40.0	21.0	44.0	10.0	30.0	3.90	38	Data of Curve 3
6:54	46.0	41.0	40.0	21.0	43.0	9.0	30.0	3.40	43	
6:57	46.0	41.0	40.5	21.0	42.0	9.0	30.0	3.30	44	
7:00	46.0	41.0	40.5	33.0	44.5	9.5	30.0	5.00	50	Light Load
7:04	46.0	41.0	40.0	23.0	43.0	9.5	30.0	3.70	41	
7:10	46.0	40.5	40.0	24.0	43.0	9.5	30.0	3.80	40	
7:15	47.0	41.0	40.0	24.0	43.0	9.0	30.0	3.70	41	
8:00	Arrive at Kansas City									

WATTMETER DATA

Time	Generator	Line	Battery Charge	Battery Discharge
6:00 P. M. May 9, '06	9983.140	0012.60	9968.66	0101.23
8:20 A. M. May 10, '06	9992.068	0008.68	9960.90	0099.54
Difference	8.928	3.92	7.76	1.69
Constant of Wattmeter	2.196	2.14	1.018	1.10
K. W. Hours	19.6	8.38	7.90	1.86

SPECIFIC GRAVITY

10:08 P. M. May 9, '06 - - - - - -	1227
8:00 A. M. May 10, '06 - - - - - -	1225

Data of Trip on Train 56
From Kansas City to Chicago, May 10, 1906

	VOLTAGE				CURRENT				
Time P. M.	Generator	Line	Battery	Field	Generator	Line	Battery	Field	Speed Miles per Hour
5:15	0.0	31.0	32.0	0.0	0.0	34.0	36.0	0.00	0
6:00	0.0	29.8	30.3	0.0	0.0	39.5	40.5	0.00	0
6:20	Left Kansas City								
6:30	40.0	35.0	34.0	15.0	40.0	18.0	21.0	2.80	53
7:08	39.0	35.0	34.5	17.0	43.0	38.0	2.0	2.80	46
7:12	38.0	34.0	34.0	17.0	43.0	38.0	2.0	2.80	46
8:04	- 8:15 Stop at Cameron Junction								
8:15	0.0	29.8	30.2	0.0	0.0	38.0	40.0	0.00	0
8:27	38.0	33.0	33.0	27.0	49.0	43.0	3.0	4.00	33
8:30	38.0	35.0	32.0	18.0	49.0	42.0	4.0	2.50	44
8:39	- 8:41 Stop at Hamilton								
10:45	40.0	35.0	34.0	36.0	41.0	20.5	17.0	4.00	33
11:06	- 11:11 Stop at Macon								
11:35	42.0	36.0	36.0	16.0	43.0	7.0	33.0	3.00	45
1:04	- 1:13 Stop at Quincy								
1:10	0.0	33.0	33.5	0.0	0.0	7.7	9.2	0.00	0
1:15	42.0	37.0	36.0	31.0	43.0	8.0	30.0	4.70	26
1:18	42.0	37.0	36.5	38.0	49.0	15.0	29.0	5.20	32
1:25	43.0	37.0	37.0	28.0	45.0	11.0	30.0	4.20	37
1:31	42.0	38.0	37.0	19.0	44.0	9.0	32.0	3.00	45
3:23	44.5	40.0	40.0	41.0	48.0	35.0	7.0	5.80	24
4-32	- 4:33 Stop at Galva								
4:35	41.0	36.0	35.0	17.0	43.0	17.0	23.0	2.80	44
5:02	- 5:03 Stop at Buda								
5:05	46.0	0.0	39.5	18.5	43.0	2.0	38.0	3.10	44
5-13	47.0	0.0	40.0	17.0	44.0	2.0	39.0	3.00	51
5:16	47.0	0.0	37.5	17.0	43.0	2.0	38.0	2.90	50
6:52	- 6:54 Stop at Aurora								

6:55	46.0	0.0	40.0	36.0	46.0	0.0	40.0	5.50	29	Data of Curve 4 No Load
6:58	46.0	0.0	40.0	29.0	41.0	0.0	36.0	4.40	33	
7:00	46.0	0.0	40.0	27.0	46.0	0.0	42.0	4.20	37	
7:02	46.0	0.0	40.0	23.0	44.0	0.0	40.0	3.70	40	
7:04	46.0	0.0	40.0	20.0	45.0	0.0	42.0	3.30	46	
7:06	46.0	0.0	40.0	17.0	41.0	0.0	39.0	3.00	51	
7:09	46.5	0.0	40.5	17.5	41.0	0.0	38.0	3.10	50	

8:02 Arrive at Chicago

WATTMETER DATA

Time	Generator	Line	Battery Charge	Battery Discharge
5:45 P. M. May 10, '06	999.256	0008.68	9960.9	0099.6
8:00 A. M. May 11, '06	10001.315	0005.28	9954.0	0097.9
Difference	8.755	3.46	6.9	1.7
Constant of Wattmeter	2.196	2.14	1.018	1.1
K. W. Hours	19.2	7.28	7.03	1.87

SPECIFIC GRAVITY

5:15 P. M. May 10, '06 - - - - - -	1223
9:05 A. M. May 11, '06 - - - - - -	1225

STRAY POWER TEST

Motor

Volts	Armature Current	Field Current	Speed R. P. M.	Watts Output	Stray Power
120	5.0	2.10	1600	600	364
120	4.8	2.00	1600	576	352
111	5.1	2.07	1540	566	345
112	5.6	1.42	1940	627	380
113	5.4	1.45	1890	610	370
113	5.2	1.97	1620	587	350
116	5.1	2.00	1670	592	370
115	5.7	1.50	1960	659	392
115	5.6	1.45	1950	645	385
112	5.4	1.55	1870	605	380
111	5.1	1.55	1890	567	375

Generator

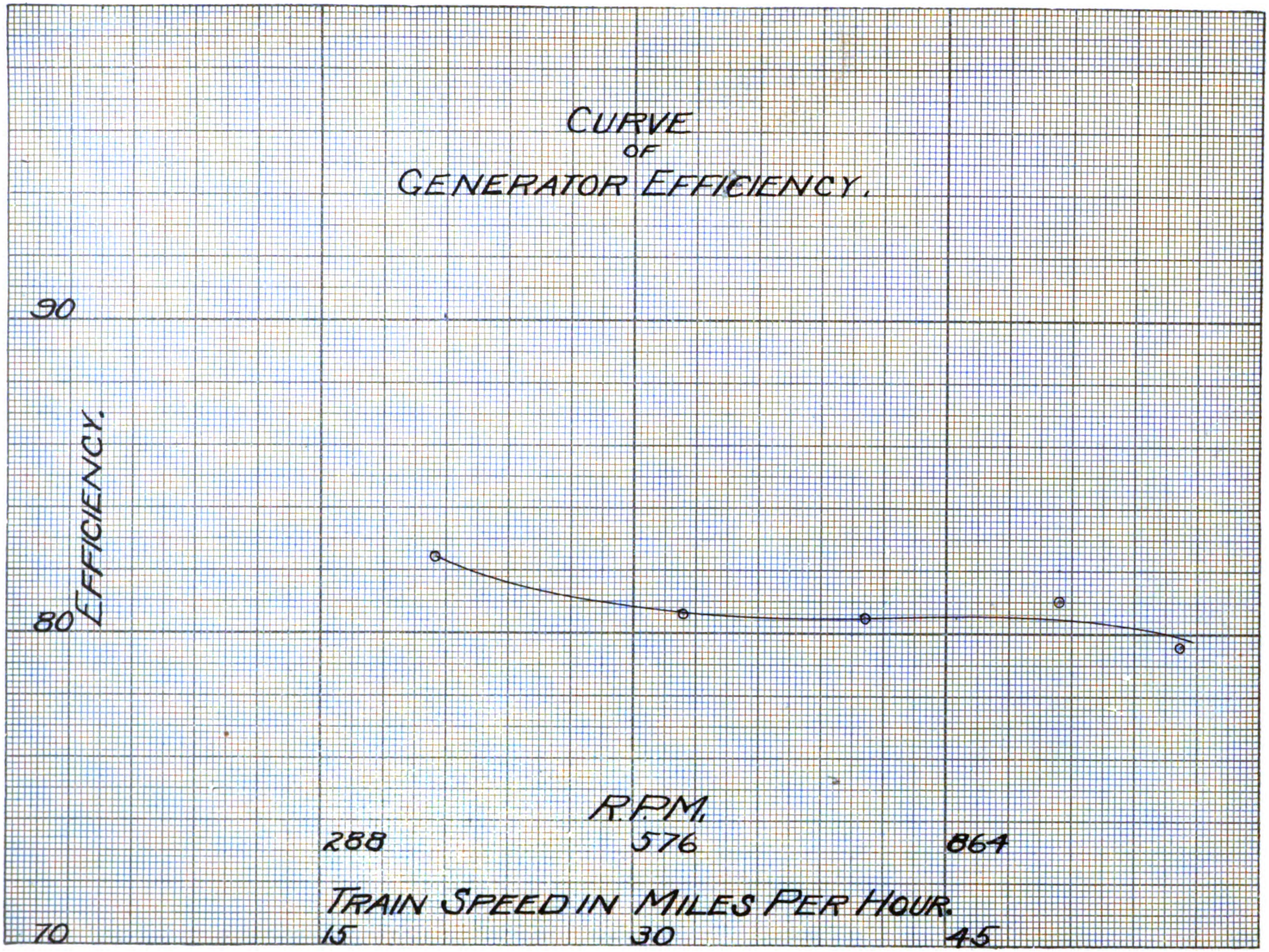
Volts	Field Current	Speed R. P. M.	Speed Miles per Hour	Stray Power and Field Watts	Generator Efficiency
34.5	0.85	634	32.5	236	80.6 %
35.5	0.85	634	32.5	224	
39.5	1.10	620	32.0	221	
39.5	1.74	770	40.0	247	
34.5	0.58	790	41.0	240	80.5 %
39.5	0.54	930	48.2	237	
34.5	0.46	970	50.5	222	81.0 %
39.5	0.44	1100	57.5	267	
34.5	0.37	1090	56.5	260	79.6 %
29.5	1.53	400	20.7	235	
34.5	0.28	400	20.7	192	82.5 %

Average Efficiency - - - 80.8 %

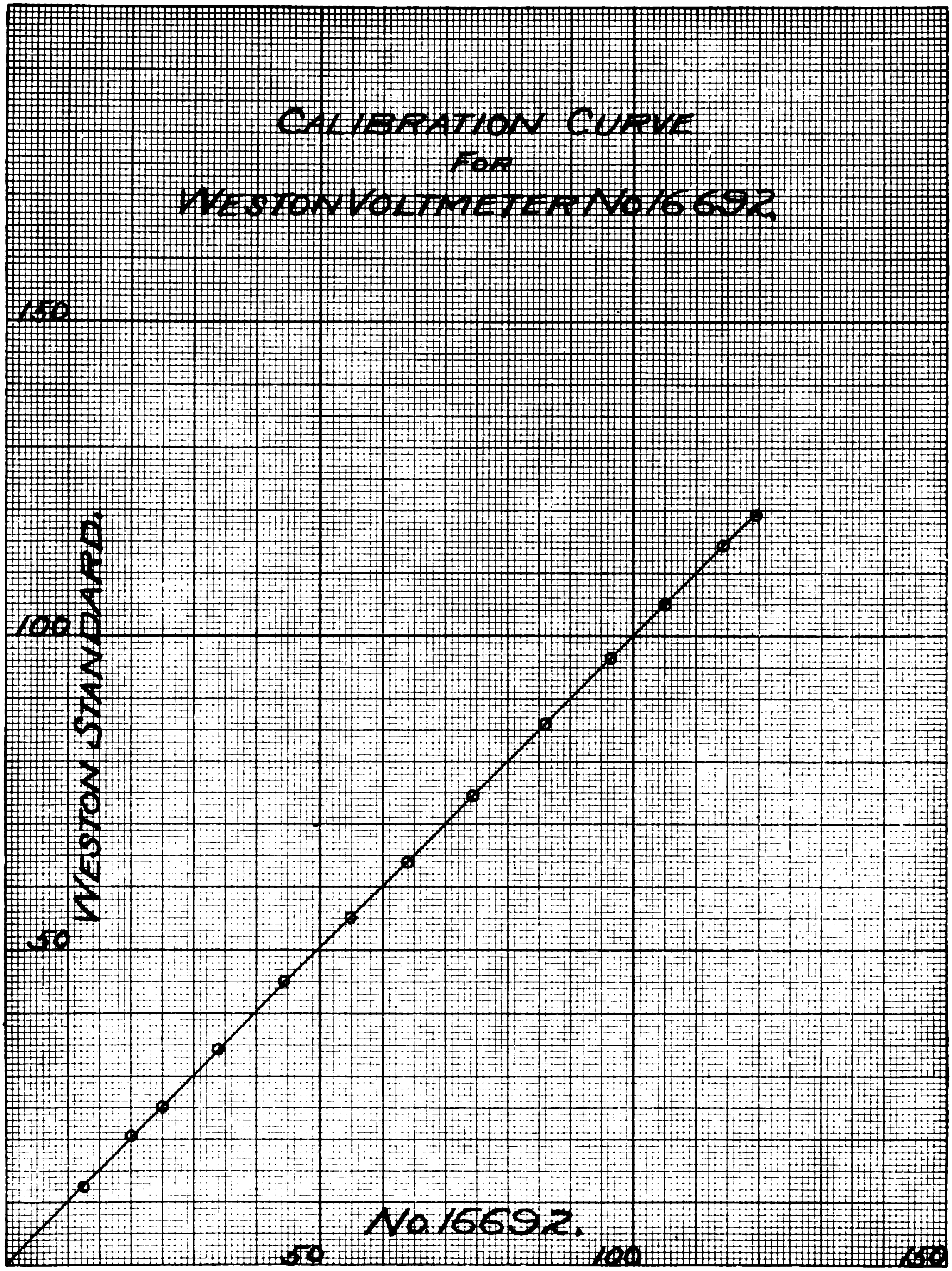
Armature resistance - .083 ohms.

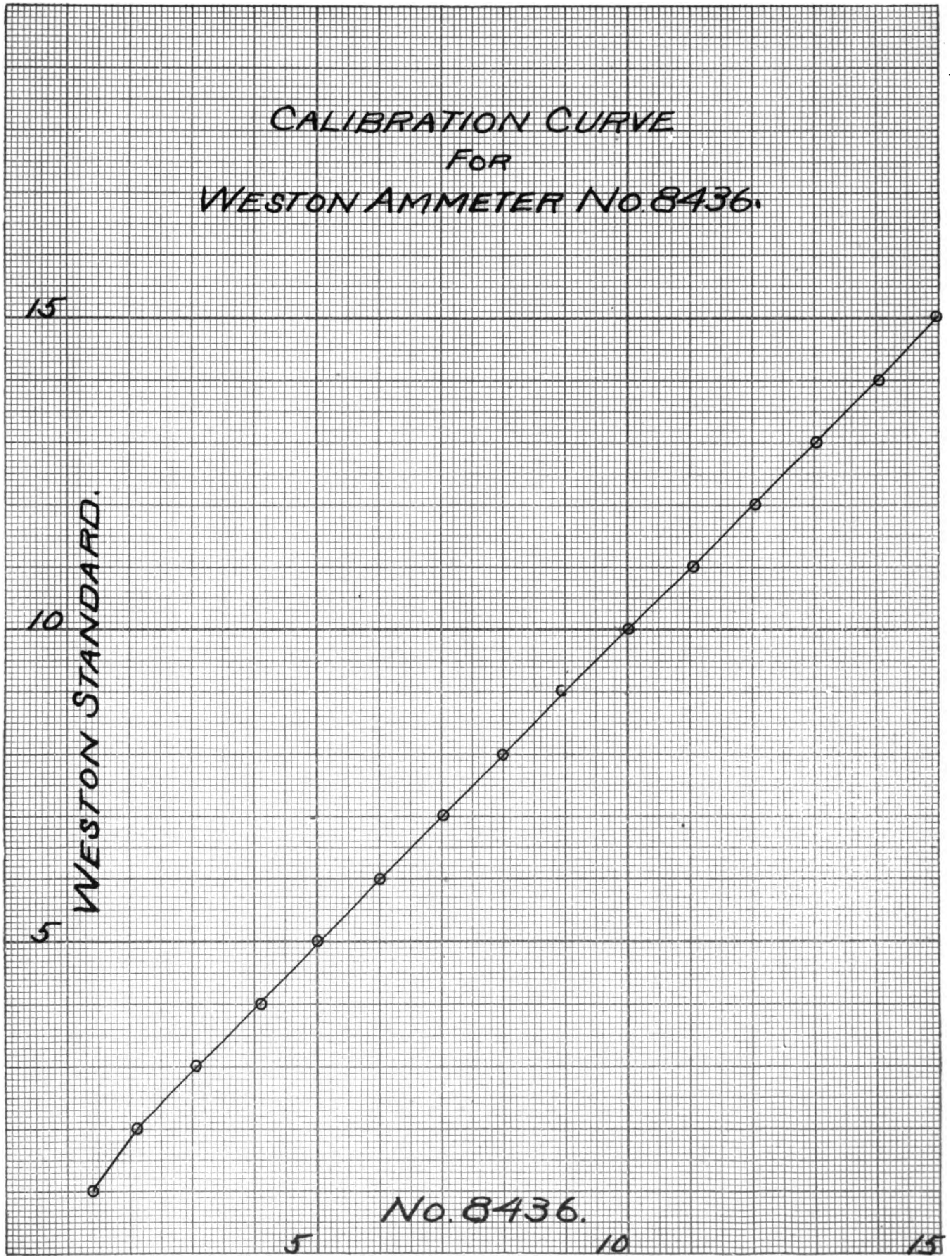
WATTMETER CALIBRATIONS

Time in Seconds	Volts	Current	Revolutions	Watts	Constant
Generator Wattmeter					
41	28	35	5	980	2.230
65.5	34	35	10	1190	2.160
63	36	35	10	1260	2.200
			Average	-	- 2.196
Line Wattmeter					
40.4	28	35	5	980	2.200
68	32	35	10	1120	2.120
59.8	36	35	10	1260	2.100
			Average	-	- 2.140
Battery Charge Wattmeter					
60	28	35	16	980	1.020
60	32	35	18	1120	1.035
60	36	35	21	1260	1.000
			Average	-	- 1.018
Battery Discharge Wattmeter					
40.8	28	35	10	980	1.110
35	32	35	10	1120	1.090
60	36	35	19	1260	1.100
			Average	-	- 1.100

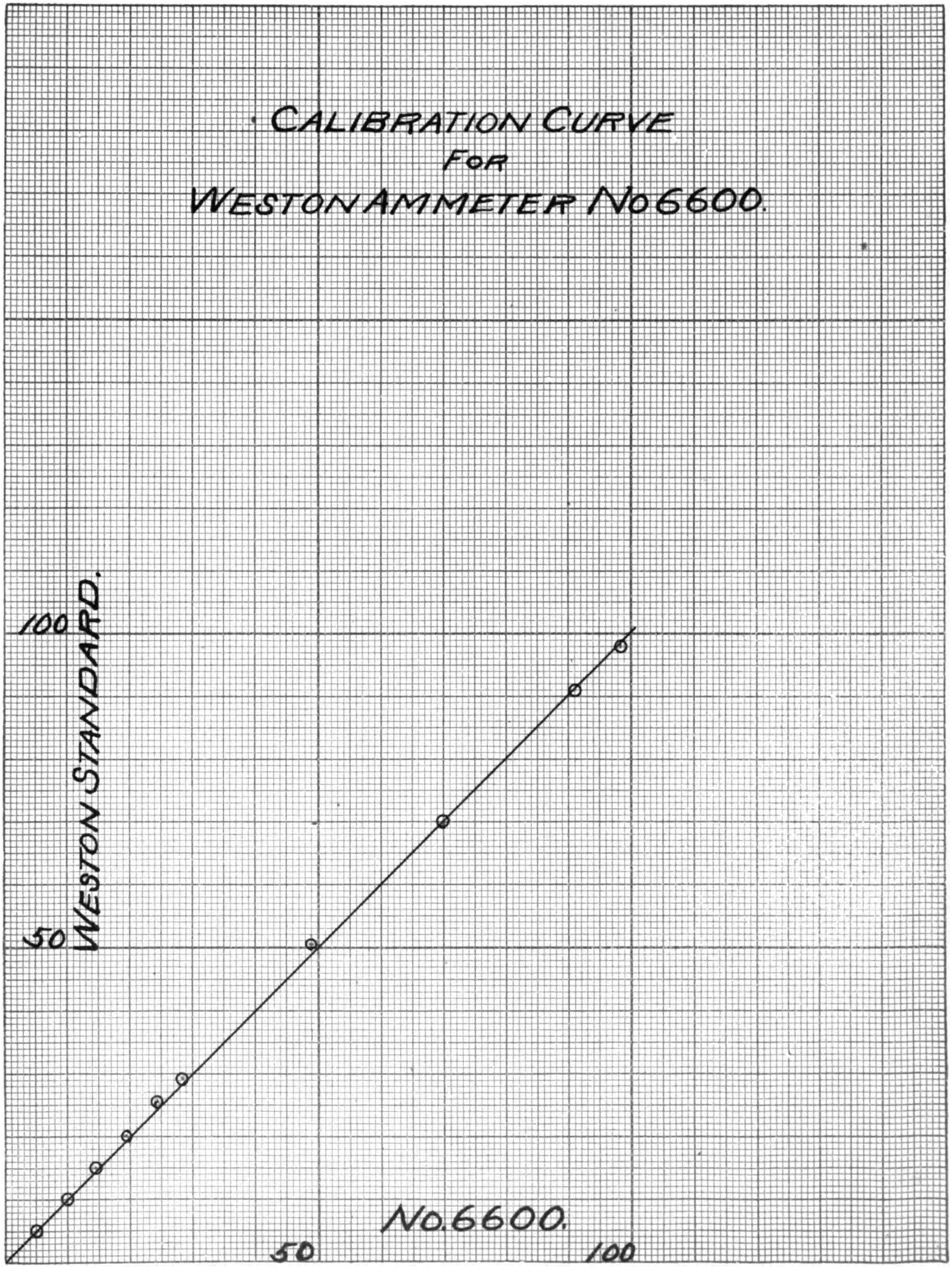


CURVE OF GENERATOR EFFICIENCY.


CALIBRATION CURVE
FOR
WESTON VOLTMETER No 16692.
150
100
50
WESTON STANDARD.
No. 16692.
50
100
150



CALIBRATION CURVE
FOR
WESTON AMMETER No. 8436.



CALIBRATION CURVE FOR WESTON AMMETER No 6600.

APPROVED Dugald C. Jackson

Professor of Electrical Engineering

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